Ministry of Technology

Report of the Steering Group on Development Cost Estimating

Volume 1 Report

LONDON: H.M. STATIONERY OFFICE
1969

SBN 11 470062 1

Foreword

by

The Rt. Hon. Anthony Wedgwood Benn, M.P.,
Minister of Technology

The problem of estimating and controlling the cost and timescale of advanced technological projects is one that has long exercised countries which have embarked on such projects. In the United Kingdom the problem has been constantly studied for more than 10 years. The Gibb-Zuckerman Committee on the Management and Control of Research and Development made a valuable contribution with its Report published in 1961. Three years later the then Permanent Secretary of the Ministry of Aviation appointed a Steering Group of officials from that Department and the Ministry of Defence to review how the Gibb-Zuckerman procedures were working in practice and to re-examine this difficult field. The Group studied in detail the practices of both the then Ministry of Aviation and of industry. Case studies were conducted in individual companies by industrial consultants. I am glad to say that industry gave its willing co-operation.

The Group reported at the end of 1966 and since then the Report has been widely discussed and considered within the Government Departments concerned and with the representative bodies of the aerospace and electronics industries. In response to a number of requests I am now publishing the report so that it may achieve an even wider circulation.

The many recommendations of the Group have been substantially accepted and are already being implemented. A number of them relate to organisation and training within my own Department—including the use of project teams and their training in modern techniques of management. Others relate to the method of carrying out large development projects and will involve Government contractors.

Although the report endorsed the principles laid down in the Gibb-Zuckerman Report, the Group was concerned that in practice project studies were not being carried out in sufficient depth. It considered that full development should not be authorised on major technically advanced projects until the main uncertainties had been resolved and a well-founded programme and estimate prepared which could be used as a basis for decision to go ahead and for subsequent control. Accordingly, the Group recommended that the project study should be more extensive, embracing more experimental, design and testing work than had often been the case in the past. The ensuing development should then be more straightforward and less subject to the hazards of technical and financial uncertainty. We expect that major projects will generally warrant this new degree of project definition. But we fully accept the Group's warning against a single rigid procedure for all types and sizes of projects.

The Group's investigation also showed that while some companies have installed effective cost control systems and are employing advanced management techniques, there remains a need to set out in detail the principles which should normally govern the management of complex development projects. To meet this need a handbook of procedures, comprising Volume II of the Report, was prepared. This handbook, or code of practice, is not intended to be mandatory but we shall expect all contractors to assess their procedures in the light of it and to use it as a guide in devising and introducing improvements.

The Report has been discussed between the Department and representatives of the aerospace and electronics industries. Whilst generally welcoming the Report, the industries have expressed concern about certain aspects, for example that the new procedures should not lengthen the period of development nor render collaboration with other countries more difficult. We have assured them that we do not expect the procedures to have this effect. It should in fact be possible to complete development programmes more smoothly when estimates of cost and timescale are not subject to serious error. The Steering Group itself recognised that it might not be possible fully to implement their recommendations in the case of collaborative projects. But the Group hoped, as I do, that we shall be able to influence our partners in the directions recommended.

I believe that all those who are interested in this difficult subject will find the Group's Report valuable and stimulating. I should like to pay tribute to the careful and thorough work which went to its preparation.

MINISTRY OF TECHNOLOGY
Millbank Tower
Millbank
London S.W.1

1st *November* 1968

Sir Ronald Melville

I submit the final report of the Steering Group on Development Cost Estimating.

Since efforts are continually being made to improve methods for estimating and controlling the cost of defence projects carried out in industry, we found ourselves investigating an evolving situation. Our studies showed that much has been achieved; they showed also that much remains to be done. Indeed, we found it necessary to examine and consider the present procedures for development at such length and in such detail that we have not been able to give the production aspects of our task the attention they deserve. These will need to be considered further when decisions, following our present report, have been taken and implemented.

Two main conclusions form the basis of our Report. The type of project study that has hitherto been normal can generally yield neither the technical and cost information which is needed for a well-founded decision on full development nor a standard against which progress can later be measured in both technical and financial terms. The Ministry of Aviation needs to adopt a more disciplined and professional approach to project formulation, assessment and control; this in turn needs to be accompanied by and will we hope inculcate a similar attitude in industry.

Our principal concern has been to make recommendations aimed at correcting these deficiencies.

W. G. Downey
Chairman

19th December, 1966

Contents

		Paragraphs	Page
Chapter 1	**Introduction**	1–7	1
Chapter 2	**The Historical Background**	8–15	3
Chapter 3	**The Changing Environment**	16–23	5
Chapter 4	**Our Approach to the Task**	24–33	7

Chapter 5 Our Internal Investigations

	Paragraphs	Page
Introduction	34	9
Staffing for project assessment and management	35–37	9
Training for project management	38–40	9
Guidance for project officers	41	10
Evaluation of development programmes and estimates	42–45	10
The contribution of the Directorate of Technical Costs to project estimating	46–54	11
The contribution of the Directorate of Accountancy Services to project estimating	55–58	12
Limitations of the Ministry's technical staff and their need for project records	59–62	13
Present state of the Ministry's project records	63–64	14
Production estimates	65	14
The organization required for project analysis	66–77	15
Data required	78–87	17
Overhead rates in Development Cost Plans	88–89	19
Responsibility for monitoring overhead rates	90–91	19

Chapter 6 The External Studies

	Paragraphs	Page
The auditors' reports	92–97	21
The consultants' industrial case studies	98–101	22
Summary of the consultants' findings		
The state of definition at the end of the project study	102–105	23
Programming	106–109	24
Development cost estimating	110–113	24
Monitoring and controlling technical progress	114–116	25
Monitoring and controlling cost progress	117–120	25
Production cost estimating	121–122	26
Records linking performance or technical characteristics with cost	123–124	26
Value Engineering	125–126	27
Design changes	127	27
Contract aspects and project delays	128–129	27
Conclusions	130–133	28

Chapter 7 The Working of the Present Procedures

	Paragraphs	Page
Implementation of the present procedures	134–136	29
Factors leading to under-estimating	137–139	29
Limitations of estimates arising from project studies	140–141	30
Types of estimate	142–149	31
Subjective estimating	144	31
Parametric estimating	145	31
Comparative estimating	146–147	31
Synthetic estimating.	148–149	31
Stages at which various types of estimate can be made	150–154	32
Production estimating and unit production costs	155–158	33
The effects of delays in taking decisions	159–164	34
Need for improved programming, estimating, and control procedures in industry	165–167	34
Relationships between the Ministry of Aviation and industry	168–172	35

Chapter 8 The American Approach to the Initiation and Control of Defence Projects

Introduction 173–175 37
Stages of the research and development cycle 176–184 37
Milestones in the life of a typical weapon system . . . 185 38
Concept Formulation and Contract Definition 186–193 38
Appraisal of U.S. procedures 194–196 41
Major differences between U.S. and U.K. approach to development 197–198 42

Chapter 9 The French Approach to the Initiation and Control of Defence Projects

Initiation of projects 199–200 43
Contract arrangements 201–206 43
Arrangements for project administration 207–208 44
Conclusion 209 44

Chapter 10 The Scope for Incentives in Development Contracts

Introduction 210–211 46
Types of incentive 212–213 46
U.K. experience 214–218 46
The Contracts Division mission to the United States 219 48
Evolution of American incentive arrangements 220–228 48
Performance and delivery incentives 229–234 50
The relevance of U.S. experience to U.K. conditions . . . 235–240 52
Conclusions 241–246 54

Chapter 11 Our Proposed Changes to the Procedures

Introduction 247–249 56
Need for better project definition and later decision point . . 250–252 56
Proposals for more detailed project definition 253–270 57
Handbook of Procedures 271–274 62
Programme reserves and general contingencies 275–280 63
Relationships between the supply Department and industry . . 281–284 64

Chapter 12 International Collaboration—The Effect of the Procedures Proposed

Introduction 285 66
Effect of our proposals on collaboration with the United States . 286–289 66
Effect of our proposals on collaboration with France . . . 290–291 67
Further difficulties in international collaboration 292–293 67
Conclusions 294–295 68

Chapter 13 Summary of Conclusions and Recommendations

Introduction 296 69
Conflicting factors in development cost estimating 297 69
Limitations of normal project study 298–299 69
Proposals for better project definition 300–301 69
Consequent increase in scope for incentive contracting . . . 302 70
Preparation and evaluation of development programmes and estimates 303–308 70
Need for timely decisions 309 71
Estimating unit production costs 310 71
The approach to development in the United States and France . 311 71
Effect of our proposals on international projects 312 71

List of Principal Conclusions and Recommendations . . . 72

List of Appendices 79

© *Crown copyright 1968*

CHAPTER 1

Introduction

1. The Steering Group was appointed by the then Permanent Secretary, Ministry of Aviation, Sir Richard Way, in April, 1964, with the detailed terms of reference at Appendix A. Its main task was:

> 'To examine and consider the methods used in industry for estimating the cost of developing and producing defence equipment (other than atomic weapons) in accordance with stated requirements and in the Department for checking such estimates; to examine and consider the methods used by both parties for the subsequent control of development and estimated production cost against approved estimates and against technical progress; and to make recommendations.'

2. Mr. W. G. Downey, Under-Secretary, Electronics and Guided Weapons Division, was appointed Chairman of the Group, and at the outset the members were as follows:

Mr. L. R. Beesly	Director-General of Aircraft Production
Mr. R. H. W. Bullock	Under-Secretary, Air B Division
Mr. J. B. L. Clark	formerly Director of Accountancy Services
Mr. L. H. Curzon	Under-Secretary, Finance and Accounts Division
Professor Ely Devons	Professor of Commerce, University of London
Dr. B. G. Dickins	Director-General, Guided Weapons Research and Development
Mr. H. L. Lawrence-Wilson	Assistant Under-Secretary of State, Research and Development, Ministry of Defence
Mr. D. E. Morris	Director-General, RAF Aircraft Development
Mr. R. E. Sainsbury	Director-General of Guided Weapons and Electronics Production
Mr. L. H. C. Sterne	Weapons Development Committee Staff, Ministry of Defence

3. Mr. Bullock, Mr. Curzon, and Professor Devons left the Group at an early stage and were replaced by Mr. R. B. Marshall, Mr. E. S. Jackson, and Mr. P. D. Henderson. Mr. Marshall was later replaced by Mr. W. P. Shovelton. Mr. E. W. G. Haynes, Under-Secretary, Contracts Division, joined the Group in February, 1965. Dr. Dickins, Mr. Morris, and Mr. Sterne changed their appointments, but remained members throughout.

4. We first met on 13th August, 1964, and subsequently held thirty-three meetings. Apart from the difference recorded in paragraph 77 our report is unanimous.

5. Our report is in six sections. Chapters 2 and 3 set out the historical background to our enquiries and the changing environment in which development is taking place. Chapters 4 to 7 deal with our approach to the task, the facts which our investigations have brought to light, and the conclusions we have drawn from them. Chapters 8 and 9 deal with the American and French approaches to development. Chapter 10 discusses incentive contracting and reviews recent American experience in this field. Chapter 11 contains our proposals for changes to current procedures and Chapter 12 reviews their implications for international projects. The report ends with summaries of our conclusions and recommendations.

6. We did not attempt to consider the Ministry of Aviation's organization for project management. This was last reviewed in 1964 and 1965 by a Working Party under the Chairmanship of the Deputy Controller of Aircraft (Research and Development), Mr. Handel Davies, in the context of aircraft weapon systems, and certain changes were made in the Controllerate of Aircraft which were designed to strengthen and unify the technical and financial management of major aircraft projects. So far as we have been able to judge, there is no conflict between these changes and certain proposals we put forward in Chapter 5 for improving the Ministry's ability to evaluate the programmes and estimates submitted by contractors.

7. Mr. J. B. Visser and Mr. T. F. Knapp were our successive Secretaries and Mr. J. R. Christie, replaced by Mr. J. B. Visser, and Mr. A. C. Gregory were in charge of our fact finding enquiries. Mr. J. B. Visser and Mr. A. C. Gregory also assisted in the drafting of our report. The case histories on the handling of certain projects within the Department were prepared by Mr. V. E. Cole, Mr. I. O. Hockmeyer, Mr. G. F. Jeans, Mr. A. B. L. Russell, and Mr. G. R. Sunderland. In addition, a special review of procedures within the Ministry of Aviation for estimating unit production costs was carried out by Mr. J. M. G. Thexton. The case histories on the handling of certain projects in industry were prepared by Associated Industrial Consultants Ltd., and PA Management Consultants Ltd., with the willing co-operation and assistance of the companies concerned. A combined team of these two firms of consultants also prepared the Handbook of Procedures which appears as Appendix M to this Report. We are grateful to them all for their labours on our behalf.

CHAPTER 2

The Historical Background

8. Although difficulties had been experienced for many years in preparing realistic initial estimates for major defence development projects and in the control of subsequent expenditure, they did not become a source of serious concern in this country (or in the United States) until the second half of the nineteen fifties. Then, at a time when the Government was seeking to limit defence expenditure, a series of cases came to light of projects whose final costs were, or were likely to be, substantially higher than the estimates at which they were first approved. Some of these projects later attracted the attention of the Public Accounts Committee, and led to considerable public criticism in Parliament and in the Press.

9. Early in 1958, in an effort to identify the main causes of underestimation, the then Ministry of Supply set up a special operational research team under Mr. W. M. Hill. In their report, submitted in July, 1958, the team showed that over a range of about a hundred projects, the average ratio of final costs to initial estimate was about 2.8. (There were of course considerable variations between projects; some had been under-estimated by a factor of five or more.) The main causes of the increases in cost were given as:

(a) changes in the operational requirements;

(b) lack of definition of the task, including the number of models or prototypes that would be needed to sustain the programme;

(c) incomplete appreciation by the contractor of the full scope of the work that would be necessary; and

(d) the effects of inflation.

The Report also drew attention to the lack of financial discipline inherent in a cost reimbursement contract.

10. Two conferences of the Ministry of Supply's administrative and senior technical staff were held to consider this report and the general problem of the proper management of development work, and early in 1959, five Study Groups were appointed to consider various aspects. No. 1 studied possible methods of improving the reliability of initial estimates; No. 2 investigated proposals for a uniform procedure for accepting new operational requirements and changes to existing requirements; No. 3 examined the scope for the introduction of incentives into research and development contracts and the forms the incentives might take; No. 4 reviewed the limit of liability clause used in cost reimbursement contracts and the associated clauses calling for technical and financial reports at regular intervals; and No. 5 re-examined the traditional division of duties between technical and non-technical staff responsible for research and development.

11. The Study Groups reported in the second half of the year and after their recommendations had been considered by the senior management of the newly formed Ministry of Aviation, the then Permanent Secretary, Sir William Strath, issued two directives in March and April, 1960, on the financial management of research and development. These directives form one of the foundation stones of the Ministry's present structure of procedures and methods of control and they are reproduced at Appendices B and C.

12. The other main source of the system in use today was the Report of the Committee on the Management and Control of Research and Development, (the Zuckerman Report). This Committee was set up in May, 1958, and its report, dated July, 1961, was published by the Stationery Office. The Committee supported a proposal put forward by the Ministry of Supply's Study Group No. 1 on Development Project Estimating by recommending that 'project studies' should be carried out for all major projects before a development contract was placed. A project study was subsequently defined as a detailed examination of the scientific and technical problems involved in developing a weapon or equipment to meet a Staff Requirement—leading up to a plan of design, development, and testing (quantified in terms of money, manpower, and time) and to an indication of subsequent production cost. It was on the results of the project study that a decision on whether to proceed to full development would be based.

13. The main elements of the system that was intended to come into force following the fusion of these two streams of thought may be outlined as follows:

(a) the customer Department was to prepare, if necessary after a feasibility study, a formal Staff Requirement which since 1963 has had to be endorsed by the central Operational Requirements organization of the Ministry of Defence and which can only be altered through a special review procedure;

(b) the Ministry of Aviation was to place a contract with a selected firm or firms to enable them to undertake a thorough study of the problems involved in developing a weapon or equipment to meet the customer Department's Requirement. Under these contracts each firm was to prepare a phased and costed technical programme controllable by stages, called a Development Cost Plan. This was to be a statement of the work to be undertaken appropriately analysed with related estimates of cost, in such a form that during the course of development, performance to a given date could be compared with the estimate to that date. The project was to be divided into its constituent technical parts and costs were to be given for each of these units under suitable headings, each split into financial years or smaller divisions;

(c) the technical staff of the Ministry of Aviation were to carry out a critical assessment of the contractor's plan to satisfy themselves that the proposed programme of development was not only the best technical method, but also the most economical method of achieving the programme. They then had to put forward their own estimate of time-scale and cost;

(d) it was to be the responsibility of the finance staff in the Ministry of Aviation to satisfy themselves that the estimate put forward by the technical staff was a valid one; that is, that the assessment of the contractor's plan had been properly carried out and that due allowance had been made in the estimate for technical uncertainties. The discharge of this responsibility was to be facilitated by close co-operation between the technical and finance staffs and the final Departmental estimate had to be agreed between them;

(e) once a contract had been placed, the technical staff were to be responsible for the efficient management of the project, that is for seeing that it was carried forward in accordance with the agreed programme, as regards the technical progress of the work, the time-scale, and the expenditure authorized in total and year by year. This responsibility was to be discharged by day-to-day contact with the contractor, who was also to be required to submit formal progress reports on technical achievement and cost at regular intervals, usually quarterly. These were to provide an opportunity for a more formal review of progress against plan in both technical and financial terms.

14. It will be apparent from this brief summary that the effectiveness of this system depends both on the contractor's competence to prepare a realistic programme and cost estimate and on the practicability of doing so at the time required by the system within the constraints imposed by the degree of technological advance required; also on his ability subsequently to control work and costs against his plan. The history of such projects as Blue Steel, Blue Streak, and the TSR.2 renewed the anxiety that had been felt in the Ministry of Aviation about the efficiency of some contractors' arrangements in these areas, and accordingly in July, 1962, the Ministry asked its main contractors to arrange for their auditors to provide reports reviewing the systems of financial control in operation for contracts placed by the Ministry and to be priced by reference to actual costs. The results of this review were still being examined when we were appointed, but it was becoming apparent that some improvements were needed in a number of companies. Certain of these had already been introduced or were under discussion.

15. Nevertheless, despite all these measures, the cost of some projects still continued to rise substantially above that originally estimated and approved and we were, therefore, appointed to examine and consider the methods used in industry and in the Ministry of Aviation for the estimation and control of defence development projects; and to make recommendations.

CHAPTER 3

The Changing Environment

16. As the new procedures we have described were gradually introduced and improved, the defence environment was changing in a number of ways. The total Defence Estimates were declining as a proportion of the gross national product, and in 1966–67 this proportion is expected to have fallen to about 6·6% compared with 7·2% in 1960–61. At the same time, the cost of development at constant prices has continued to increase as technology has advanced. This has led to the situation, already described in the Report of the Committee of Inquiry into the Aircraft Industry[1], in which production runs have tended to become shorter and unit prices higher. The rise in unit price is even steeper if amortization of the development expenditure is included in the calculation.

17. The increasing cost of development and production and the severe consequences on the re-equipment programme of serious errors in estimating have brought an increasing awareness of the importance of unit production prices. This trend has been given further emphasis by the greater refinement of the arrangements for the forward planning and budgeting of defence expenditure. Since these arrangements cover the current year and the following ten years, it is necessary from the start of development to pay close attention to possible future production commitments and to make provision in the later years in accordance with the best estimate that can be made of the likely unit production price.

18. The steady rise in the total unit cost of development and production and the continuing difficulties with the balance of payments have also led to more vigorous attempts to ensure as far as possible that any equipment developed will be competitive in the export market since sales to customers abroad not only contribute to the general export drive, but should also both reduce unit production prices to the British Services and bring in receipts through the R. & D. levy to set against the cost of development. In addition, there has been a movement towards international collaboration in development as a means of reducing the burden of the development cost on each country and also of widening the market for the resulting equipment[2]. Examples of such collaboration are the Anglo-French Martel air-to-surface guided weapon, the Anglo-French Jaguar aircraft, and the Anglo-American advanced jet lift engine. We expect both these trends to intensify over the next few years.

19. Because of the inevitable differences in approach between countries, it is not always possible on development projects subject to international collaboration agreements to follow the procedures that we would aim to use for a national equipment. This is a point which must be allowed for in any suggested changes to current procedures and we return to it in Chapter 12.

20. The Ministry of Aviation's organization for the control of major development projects has also been changing. For many years, the organization has been divided into technical areas, (for example, airframes, aero-engines, electronic equipment, and guided weapons); into phases of activity, (research, development, production, and inspection); and into function, (technical, financial, and contractual). This has proved satisfactory for the project which is largely confined to one technical area or where the inter-faces with other development areas can be well defined and their inter-relation presents no serious problems. It has limitations, however, when applied to a major weapons system which requires the concurrent development and integration of a number of complex and inter-related equipments in different technical areas, each of which may represent a major technical advance. In these circumstances, the difficulties of preparing programmes and estimates are greatly multiplied. The problems of co-ordination which arise on this type of project have led to the concept of a project team under a Project Director who has technical and financial authority within the limits of approved estimates of time and cost for the work to be carried out by the main weapons system contractor and co-ordinating responsibility for the project as a whole[3]. This concept is evolving and further changes may be expected in the coming years.

21. Advanced development by its very nature can never be susceptible to precise estimating. The basic obstacle to better initial estimates of cost has been and will remain the various types of uncertainty associated with the development of new weapons and equipment; uncertainty about the Staff Requirement which may have to be altered during the course of

development because of changes in the international scene or in strategic policy or in the range of technological possibilities; uncertainty about the specification which translates the Requirement into engineering terms and about the work that will have to be done to meet it; and uncertainty about the technical problems that will arise and the effort and time that should be allowed for their solution.[4]

22. The difficulties of preparing and presenting estimates for development work are increased by some of the present estimating conventions. For example, the Treasury instruction which lays down that estimates must be prepared at current prices gives rise to a presentational problem, because, if inflation continues, the actual cost in money terms over, say, seven years, will turn out considerably higher than the initial estimate and thus make it appear that the initial estimate was too low. This may not in fact be true. There are also problems concerned with the substance of the estimates: for example, there is evidence that some overhead costs are rising faster than costs charged direct. If and where this is occurring, an estimate based on current or recent overhead rates will also prove too low when compared with final costs.

23. The problems of estimating for development work are also increased by the fact that re-equipment can now only take place at infrequent intervals, (so that each new generation must represent a considerable advance over its predecessor), and also in some cases by the special difficulties associated with international collaboration. The best that can be done in these circumstances is to aim at setting the decision point on whether to proceed to full development at the stage when the uncertainties have been reduced to an acceptable extent. An important part of our field work was therefore to assess the reliability of the information that was available on a selection of projects started under the new procedures at the time when the decisions were taken to go forward to full development.

REFERENCES

1. H.M.S.O. Cmnd. 2853 of 1965, Chapter 7, paragraph 102.
2. Current policy on international collaboration is described in H.M.S.O. Cmnd. 2902 of 1966, Statement on the Defence Estimates 1966, Part II, Defence Estimates 1966-67, pages 45 and 46—Interdependence.
3. Ministry of Aviation Handbook of Controller of Aircraft Instructions, (AV.P.88), Chapter 111, Aircraft Project Management.
4. A full discussion of the part played by uncertainty in weapons development is contained in 'The Weapons Acquisition Process—An Economic Analysis', Peck and Scherer, Harvard Business School, 1962.

CHAPTER 4

Our Approach to the Task

24. We decided at an early stage that it was essential for us to ascertain in some detail how the new procedures were being operated both in the Ministry of Aviation and in industry. We considered that the evidence we needed could best be obtained by commissioning a series of case histories on how particular projects had been handled, the projects selected to be at various stages in the development cycle and to cover several different technical areas and a number of the Ministry's principal contractors. If possible, the same projects should be studied both internally in the Ministry and externally in industry since this would help to illuminate any inter-face problems.

25. Our first thought was that these studies might be carried out internally by officers of the Ministry of Aviation and externally by people seconded to the Ministry for a period from the industries concerned. The latter proposal did not prove practicable, because of difficulties over commercial security. It was therefore proposed to the two trade associations mainly concerned, the Society of British Aero-space Companies and the Electronic Engineering Association, that management consultants should be used for the studies in industry and this they agreed on the understanding that negotiations would also take place with each contractor separately before a particular case history was put in hand. Detailed terms of reference for the consultants were drafted and agreed; these are reproduced at Appendix D.

26. Two firms of consultants were selected, Associated Industrial Consultants Ltd., and PA Management Consultants Ltd. A list of the projects and companies they covered is at Appendix E. Each case history was divided into two parts; a statement of fact, which was agreed with the company concerned, and the consultants' comments on those facts. These comments were shown to the company, but it was not asked to agree them. Each company was, however, invited to comment either on the particular project or on the general problem of development cost estimating and control, and a number of them did so. In the final stages of our enquiries, the two firms of consultants provided a combined team to summarize the conclusions reached, to identify the improvements which they considered necessary, and in collaboration with our Liaison Officers and with the benefit of advice from many individuals in industry and in the Ministry of Aviation, to recommend procedures for the future programming, estimating, and control of development projects. We have taken account of this further assignment in Chapter 11 and the Handbook of Procedures they prepared is included as Appendix M.

27. The case studies within the Ministry of Aviation were carried out by the Ministry officers mentioned in paragraph 7. Their detailed terms of reference changed as the studies proceeded, but their main task throughout was to establish for the selected projects the steps taken by officers of the Ministry to check the successive development programmes prepared by the contractor during the life of the project and the translation of these into effort and cost, and his successive estimates of unit production cost; also to determine the methods used by the Ministry for the subsequent control of development, and for the assessment of physical progress against expenditure in relation to the overall plan. A list of the case histories they prepared is at Appendix F, and it will be seen from this that five of the eight projects they examined were also considered by the consultants.

28. We also arranged for a number of other enquiries and were informed of the results of work being undertaken in related fields. These are referred to in more detail in the appropriate section of later chapters, but are summarized here to give a picture of the ground we have covered.

29. We set up a working party on project cost recording and analysis to conduct a pilot investigation in two selected areas because we became concerned about the lack of readily available information on the content, phasing, and cost of past projects which technical branches could use in assessing these aspects of new proposals. The conclusions arising from these investigations are contained in Chapter 5, which also includes our recommendations for strengthening the Ministry of Aviation's organization for this type of analytical work.

30. We have already referred in paragraph 14 to the reports, prepared at the Ministry of Aviation's request in 1962 by the auditors of thirty-seven of the Ministry's principal contractors for development work, about the systems of financial control in operation at these companies on contracts to be priced by reference to actual costs. The results of this exercise were summarized for us by the Director of Accountancy Services and we agreed with his view that this general approach, while it had made a useful contribution to the improvement of the systems at a number of contractors, had necessarily been limited in its scope. We felt it essential to examine in addition the methods of technical programming and resource calculation which lie behind an effective system of financial control and this was one of the reasons which prompted us towards obtaining case histories on the handling of specific projects in industry. Further details of this accountancy review and our conclusions from it are set out at the beginning of Chapter 6.

31. We also considered three reports on incentive contracting, both in this country and abroad. This was an important part of our work since if incentive contracts could be used successfully, they could do much, particularly when placed at a fixed or maximum price, to reduce the present difficulties within Government Departments over the forward budgeting of expenditure on defence research and development. Chapter 10 is devoted to our researches in this area, which were aided by a Contracts Division mission to the United States.

32. As it seems likely that there will be an increasing number of projects, both defence and civil, which will be developed in collaboration with at least one other European country, we paid special attention to the project initiation and control procedures used in France. The French approach, which is very different from ours in a number of ways, is outlined in Chapter 9. The American approach, which is already well known to many in Government defence circles in this country, is summarized in Chapter 8.

33. Finally, the investigations we made and the case histories we received led us to look again at the procedures in the Ministry of Aviation and in industry for project assessment, the preparation of technical programmes and cost estimates, and the subsequent control of projects against these programmes and estimates. Our conclusions on these points and our recommendations are contained in Chapters 7 and 11.

CHAPTER 5

Our Internal Investigations

Introduction

34. The case histories which were prepared of how selected projects were handled inside the Ministry of Aviation were aimed primarily at identifying any weaknesses there might be in the methods employed for assessing technical programmes and cost plans and for monitoring and controlling progress and expenditure against them. As a result a number of points have been brought to our attention.

Staffing for project assessment and management

35. The first was that there was a severe lack of adequate staff in the responsible technical branches in the months immediately preceding the placing of the project study contract, and also during the project study stage itself. We appreciate that there is a limit on the number of staff available to the supply Department at any time, and that during this early period the project does not form part of the approved development programme. Nevertheless, at least the nucleus of the project team must be in post some time before the project study begins, since agreement should be reached with the chosen firm before the contract is placed on the scope and depth of work that will be necessary for the preparation of a meaningful development programme and cost plan. Moreover, during the course of the project study many points will arise which need decisions by the supply Department, or at least its concurrence, such as the balance to be drawn in particular areas between performance, time, and cost, and the assumptions to be made on, say, the rate at which development flying or engine bench test hours will be accumulated. By its end the foundations should have been laid for any subsequent development programme that may be authorized and it will become increasingly difficult to alter these without disrupting the whole project.

36. We therefore repeat the recommendation in our interim report that, for all new projects, the nucleus of the project team should be formed in time to allow it to take part in the discussions on the content of the project study. It should be progressively strengthened thereafter so that it can make an effective contribution to the preparation and assessment of the Development Cost Plan on which the decision to proceed to full development will be based.

37. A further source of weakness, which we also recorded in our interim report, has been the high rate of staff turnover in technical branches and also in the associated finance and contracts branches. This is illustrated in Appendix G, which clearly demonstrates the need for greater continuity. The position has been made worse in many technical branches by the number of Service officers employed. These rarely serve more than three years, sometimes less, and often they have no previous experience of project management. They receive no special training and as a result they cannot be as effective, at least for the first part of their tours of duty, as the importance of the task demands. While career planning often makes it difficult to retain staff on project management for long periods, we take the view that the primary purpose of staff employment is the execution of a Department's work as expeditiously and efficiently as possible. We therefore repeat the recommendation in our interim report, that steps should be taken to extend the length of tours of duty of Service officers in key posts, and to ensure that staff within a supply Department posted into branches engaged on project work remain for longer periods. Where changes cannot be avoided, a reasonable period of overlap should be allowed.

Training for project management

38. On major projects, project management is fast becoming a highly specialised field requiring a knowledge of modern programming and control techniques, such as network analysis and budgetary control by task, which are outside the normal experience of a Service officer or of those engaged on research in a Ministry Establishment. This led the management consultants who carried out the industrial case studies, and who therefore came into contact with a number of the Ministry of Aviation's project management staff, to suggest that there should be a

separate professional class of project managers. This would enable more attention to be paid to the recruitment of people with the requisite personal qualities, would facilitate specialist training, and would ensure greater continuity of experience both in particular posts and in the field as a whole. The more senior posts would be filled by those who had proved themselves capable at a lower level.

39. While we agree with the general line of thought behind the suggestion for a separate class of project managers, we do not think this necessary to achieve the aims we have in mind. Such a class could not easily be fitted into the present structure of scientific and professional classes in the Civil Service and we consider that it will be sufficient if officers, both Service and civilian, who show an apparent aptitude for project management are earmarked for special training and then spend much of their careers on this type of work. We include at Appendix H an illustrative, though not necessarily definitive, syllabus for an intensive two-week residential course. This we regard as a first step towards obtaining a more professional approach to the task. Although this course is intended primarily for members of technical branches at all levels, some places should be reserved for other branches with responsibilities in or connected with the development field, such as Production, Finance, Contracts, Technical Costs and Accountancy Services.

40. This need for greater professionalism in project management has two important implications for staff policy. Firstly, project management must be regarded as an important function in its own right, having its own qualifications and expertise. In the selection of people for appointment to senior posts in 'project directorates' controlling large projects, major weight must be given to their managerial ability. Moreover, due weight should be given to their possession of these qualities in any review of their suitability for promotion. Secondly, nobody should be appointed to the senior project management posts unless he has already had some experience in the field and has acquired some knowledge, preferably through formal training, of the techniques that he and his staff will need to use.

Guidance for project officers

41. We also consider that better guidance should be given to project officers on their responsibilities. At present, these are mainly, though not entirely, defined in Notices or Instructions issued by the Controller of Aircraft or the Controller of Guided Weapons and Electronics. We consider that a more concise, coherent, and self-contained document is required to serve as a handbook of instructions to project officers on how they should go about their duties. It should, for example, indicate the particular information they should seek to see included in Development Cost Plans by contractors and the questions which they should ask firms when scrutinising these plans. It should also include check lists as aids to ensuring that all the constituent tasks (for example, preparation of Appendices A and Service publications), have been provided for in development programmes and estimates. By these means, we would hope to achieve a more common approach to project matters, the lack of which we have noted with some concern. Such a handbook would also provide a work of reference for the training course we have recommended.

Evaluation of development programmes and estimates

42. Under present instructions, the technical staff of the supply Department are charged with the responsibility of carrying out an evaluation of the Development Cost Plans submitted by contractors both at the end of the project study stage and subsequently at intervals during the development programme. This evaluation is a critical preliminary to the process of deciding whether to authorize, or continue with, development: if it is not carried out effectively, the decision will be ill-founded and may prove to have been wrong. We therefore examined the the operation of the Ministry of Aviation's own internal checks on contractors' development programmes and cost plans.

43. A Development Cost Plan is (or should be) constructed in three stages. First, in the light of the conclusions of the project study, a phased programme of work is prepared; second, an estimate is made of the effort and time that will be needed to carry it out; and third, these physical quantities are translated into money, taking account of other prime costs and also of overheads and profit. This plan is necessarily broadly based in the first instance, but its

definition improves with successive issues as knowledge increases. Eventually, a programme emerges in which the tasks and their content have been mainly defined and which is subject only to the residual uncertainties on the outstanding part of the programme. These will remain, though on a decreasing basis, until completion. Nevertheless, it is inherent in advanced development work that even at a late stage in the programme there can be no assurance that unexpected major difficulties will not arise.

44. Our investigations have shown that the technical branches' main scrutiny generally falls upon the technical content of the contractor's proposed programme of work. This scrutiny includes a check that the quantities of prototypes or models assumed will be adequate; that a proper and realistic test programme, so far as it can be foreseen at the time, has been prepared; and that no important items of work have been forgotten. Some attention is paid to the proposed level of effort, to its distribution between the main sectors of the programme, and to its phasing over time. However, and particularly on Development Cost Plans at the project study stage, only a broad appraisal is made of the cost estimate; examination being limited for the most part to overall comparisons with other projects or areas of projects in the same field on which information happens to be available.

45. Whatever may have been the success of this approach in establishing the validity of the contractor's proposed programme of technical work, it is clear that, in many cases, it did not lead to the realization that the effort and cost had been seriously under-estimated. This fact emerged only later as work progressed and the full extent and magnitude of the task became apparent. Measures need to be taken, therefore, to improve the Ministry's ability to carry out a proper evaluation of contractors' programmes and estimates of development costs, particularly those which form the basis for a decision on whether to proceed to full development.

The contribution of the Directorate of Technical Costs to project estimating

46. We first considered the contribution that might be made by the staff of the Directorate of Technical Costs. We were helped in this by having among our members Mr. L. R. Beesly, the Director-General of Aircraft Production, who was Chairman of the Working Party, which reported in July, 1964, on the functions, methods of working, organization, and staffing of the Directorate.

47. The main function of the Directorate of Technical Costs is to advise, in response to requests by Directors of Contracts, on the prime costs of manufacture, under efficient management, of supplies ordered or to be ordered by Government Departments. The Directorate also maintains an oversight, when requested by Directors of Contracts, on work under research and development contracts placed on a cost plus profit basis in order to ensure that costs claimed by the contractor for the work done are fair and reasonable[1].

48. The Working Party recommended that the functions of a technical costs organization should include a direct responsibility relating to the estimating of prime costs from the inception of a project to its completion. The extent of the contribution that the Directorate could make would of course depend to a great extent on the stage which the project had reached. To associate the Directorate with projects from their initiation would have the added advantage that, when accurate estimates were required at the final stage for price-fixing purposes, technical costs officers would have a very considerable knowledge of the history and detail of the equipment. This would assist them in formulating more accurate estimates than would otherwise be possible[2].

49. The Working Party went on to propose that, on development projects, technical costs officers should comment on the Development Cost Plan. The Directorate should also take part in the regular reviews of projects and in the assessment of the probable cost of the work to completion. After the placing of a development contract, unless it was at a fixed price, it should maintain an oversight of the work on behalf of the Director of Contracts and the Project Director. It should also, in conjunction with technical branches, advise the Project Director on the progress of technical achievement. Technical costs officers should attend design change meetings and keep abreast of development[3].

50. These recommendations were accepted by the Ministry of Aviation as objectives to be achieved, but it was felt that until additional staff could be provided, the effort available within the Directorate would have to be directed primarily to ensuring that their main task of giving advice to the Directors of Contracts for the purpose of price fixing would be effectively carried out.

51. We feel, however, that it must be made clear that the main experience of Technical Costs is in preparing or checking estimates of the prime cost of manufacture, using drawings prepared by the contractor wherever possible. The limited scope of the project studies carried out in recent years had meant that few drawings, other than general assembly or scheme drawings, have been available when contractors prepare their initial Development Cost Plans, and this has inevitably restricted the value of any contribution that Technical Costs may have been asked to make to their assessment. Indeed, design information has been so lacking at this point that inaccuracies due to bad estimating of the design concept have probably been completely outweighed by cost increases arising from the subsequent technical evolution of the design and of the development programme.

52. Even if the project study is extended to improve the definition achieved at the end of that stage, development must proceed for some time before many areas of the design will have crystallized sufficiently to enable Technical Costs to apply their normal estimating techniques. Even then, uncertainties will remain; development is essentially a process of experimental work leading to design, prototype manufacture, and testing, followed by redesign and retesting to overcome the defects revealed, and any assessment of the effort and cost involved and their effect on the overall programme must depend very much on judgment based on experience. The Directorate has little, if any, direct development experience to bring to bear on these problems; nor has it records of past development performance to enable it to assess the validity of the programme proposed. In these circumstances, and as changes and extensions to such programmes are the major cause of cost increases, the contribution which Technical Costs can make to estimating in the formative stages of a development project must necessarily be limited.

53. As the project progresses and the design becomes clearer and increasingly translated into drawings, Technical Costs' potential contribution to the supply Department's check of the validity of the contractor's estimate of cost becomes greater. If, therefore, the proposal for a Project Definition phase we recommend later in this Report is adopted for the larger, more complex projects, it should be possible to bring the Directorate into the picture to a greater extent and to expect technical costs officers to play a more important part in the assessment of the manufacturing element of the Development Cost Plan prepared at the end of that stage. Nevertheless, it must be emphasized that Technical Costs will only be able to estimate on the basis of the design as then envisaged whereas the supply Department needs to estimate on the basis of what the design is likely to become, and of the redesign, rework, and retest that will be required to achieve it. Moreover, until the Directorate is staffed to perform adequately its primary task of providing advice on prime costs to Directors of Contracts for price-fixing negotiations, nice judgment will be required to determine the extent to which effort should be diverted to assist Project Directors in validating development cost estimates.

54. Much the same line of argument applies to the estimates of unit production cost prepared during development. In the early stages of development when few drawings exist even of, say, the first prototype or electronic model, there is little that the Directorate can contribute. But as more and more development drawings become available and these approximate more and more to the expected final design, then the Directorate can come increasingly into the picture until the point is reached at which they are able to provide a reasoned criticism of the contractor's estimate, if not an independent estimate of their own.

The contribution of the Directorate of Accountancy Services to project estimating

55. We also considered the contribution that could be made by the Directorate of Accountancy Services to the evaluation of contractors' estimates.

56. In assessing a cost estimate, and particularly when comparing competitive estimates, the technical branch needs to know the broad outlines of the cost allocation system used by the contractor. This is agreed in detail by the Directorate of Accountancy Services, on behalf of

the Ministry, and it is therefore in the best position to explain each contractor's system to the technical branch to the extent that this is necessary and to confirm that his cost plan has been prepared in accordance with it and that the cost plan has been presented in a form which will allow direct comparison with the subsequent actual expenditure figures produced by the firm's cost accounting system. Most of the costs which are variable in terms of the project will probably be charged direct, but this is not always the case and the technical branch needs to know if it is dealing with a contractor with a very narrow base of direct charging since this will affect its methods of supervision.

57. The Directorate is also in the best position to advise on overhead rates. When a contractor claims to be using agreed actual rates or provisionally agreed actual rates, it will be able to confirm that these are correct. When the contractor is using internal budget rates or he is giving an estimate of future rates, it will be able to advise on the reasonableness of these in relation to the most recent information available. Since overheads can represent 40% or more of total cost, it is important that this advice should be brought to bear as part of the evaluation of a cost estimate and we recommend that technical branches should be required to consult the Directorate on these aspects.

58. If these consultations are undertaken regularly and special approaches are made as necessary, we do not think any significant extra benefit will be obtained from making the professional accountant a member of the project team. Any extra effort that may be available in the Directorate should be devoted rather to a regular and systematic review of the estimating and cost accounting procedures of each of the Ministry of Aviation's principal contractors to ensure that they will enable proper control to be exercised over expenditure on Ministry account.

Limitations of the Ministry's technical staff and their need for project records

59. It has to be recognized that the Ministry of Aviation's technical staff, whether at Headquarters or at Research and Development Establishments, are not in a position to prepare an independent assessment based on a detailed breakdown of the task. Not only are they not fitted by their duties for this, but they have no first-hand continuous industrial experience to draw on as compared with a firm whose staff will be concerned on a day-to-day basis with the appraisal and breakdown of tasks, the allocation of effort to them in the knowledge of the facilities available within their organization, and their routine planning and costing. We consider, therefore, that the preparation of detailed programmes and estimates is a field of activity which must be left to industry with its greater knowledge and skills and that the supply Department should not attempt to match such estimates.

60. Even though the supply Department is not well placed to set out a fully analysed and detailed development programme and cost plan, it is essential that it should supervise the firm carefully to ensure that they prepare their programme and estimate in a systematic and thorough way and that on appropriate matters, for example, the extent of coverage (such as technical publications and Service test equipment) and the correct overhead rates to use, they accept guidance from the Department. Moreover, information should be available to the supply Department on many more projects and over wider fields of activity than is available to individual firms and at the early formative stages of a project this accumulation of experience should enable it to make at least as good if not better estimates of costs on a comparative basis than can be made by industry. It should also be able to make informed judgments based on past experience on the validity of the work and cost content of the main areas in a more detailed programme and estimate when the project has advanced sufficiently in definition to enable these to be prepared.

61. For the supply Department to be able to make use of this advantage, however, it is essential for it to be able to bring experience of past projects effectively to bear. Modern projects may take seven years or more to come to fruition and this, coupled with the fact that some projects are cancelled and that officers, both Service and civilian, are posted elsewhere, means that personal experience is necessarily restricted. In consequence, only limited competence exists within technical branches for the assessment of firms' proposals. Project teams must, therefore, be able to refer to all possible sources of information and advice and it is essential that past experience should be adequately documented so that it is relevant, accessible, and recorded in a usable form.

62. Although we have been impressed by the evidence we have received that in a number of technical areas, and particularly in the electronics field, the rate of technical advance has been such that past experience may not be a reliable guide to future projects, and that, in certain circumstances, it may be misleading, we find it difficult to accept, as has been suggested, that records of past experience should be disregarded. We accept that past experience will require very careful interpretation when used as a guide to future performance; but we believe that properly planned records are essential and that, provided uninformative and unnecessary detail is avoided, the more comprehensive and well-defined the records, the greater the chance of using the experience which they represent to make meaningful judgments on new programmes and costs. In major projects, it is unlikely that all areas will be areas of major technical advance, and some of them may well be comparable with parts of earlier projects.

Present state of the Ministry's project records

63. The need throughout the Ministry of Aviation for systematically recorded information on past projects has been recognized for some time, but our investigations have disclosed that unfortunately much of the information required is not readily available, and where it exists it is not suitably recorded. Moreover, little progress has been made towards devising a suitable system of recording. One administrative Division has introduced a new series of project history cards, but an examination of these showed that they contain purely financial information on a time basis in a form which provides no correlation with the physical state of the work. Continuous records of projects which exist in other general branches, such as Contracts Division or other administrative branches, are designed around the basic function of the branch and do not take into consideration, at least directly, the need to provide data for subsequent analysis. Although analysis of these new project history cards can give curves of expenditure and payment patterns which are of use in estimating and controlling new projects, the weakness of these records for planning purposes is that costs are recorded against time, which merely indicates the volume of resources employed. We believe that the data actually required is of cost against achievement, since tasks may be tackled in different ways or at different rates on different projects. Such data also enable areas of particular difficulty to be identified.

64. There has so far been little systematic attempt to keep records relating technical progress to cost in a way which would aid the detailed assessment of Development Cost Plans. In fact, the opposite is true; on completion of a project and the disbandment of the project team files are sent away to archives and it becomes almost impossible after a time to locate and retrieve the information required if only because of the difficulty in obtaining records of the relevant file themes or numbers. It is true that in the Controllerate of Aircraft, the Project Time & Cost Analysis Branch (PTC(An)), formed from the old Technical Development Plans, can provide some information about airframe development, but this is not in a form in which comparisons can easily be made, nor is it broken down within areas of a project; consequently, whilst it may be applied to the type of projections made at the feasibility stage, it is of little value for assessing the detailed validity of a built-up programme at the project study stage. Current work in PTC(An) may enable the global airframe estimates to be broken down into major functional areas of a project, but the detailed records of development programmes, and how they have changed with time, which would enable a further breakdown to be made into the constituent physical areas of a project, do not exist.

Production estimates

65. Much of what we have said about the evaluation of development estimates and the limited expertise available applies equally to early production estimates. During the initial stages of a major project the production estimates made by the Ministry of Aviation have necessarily been highly tentative as the information at the end of the project study stage tends to be little more than an outline general assembly drawing. Our studies have shown that estimates at this stage have, in consequence, been unreliable. This has led to attempts, for example, by the Aircraft Production General (Plans) Branch in the airframe field, to establish correlations between unit production cost and certain physical parameters of the system in order to provide a check that any early estimate prepared is of the right order of magnitude. We consider that these efforts should be encouraged and the conclusions we have reached on the need to be able to bring past experience to bear during the formative stages of development apply equally to the preparation or assessment of early estimates of production cost.

The organization required for project analysis

66. As we have recorded in Chapter 1, we have not regarded the question of the Ministry of Aviation's organization for project management as within our terms of reference. However, as we have shown, there is a clear need, if uninformed assessment and undue reliance on intuitive judgments are to be avoided, for a drive to record and collate the corporate experience of the Ministry on project programmes and costs, so that technical branches can improve their ability to prepare independent programmes and estimates of possible new projects, and to undertake a more effective and critical scrutiny of the programmes and estimates submitted by contractors. This will require a more systematic analysis than has been achieved so far, of how programmes have changed throughout development, and the examination of the inter-relation of costs, time-scales, and technical characteristics of particular equipments and parts of equipment. This in turn will require a larger and more professional organization than exists at present. We have, therefore, given some consideration to the organizational steps that might be taken to this end.

67. In the Controllerate of Aircraft, the need for a service in the airframe field to collect, collate, and analyse historical data on the costs, time-scales, and content of development and production programmes in order to provide an advisory service to the technical branches who have the formal responsibility for assessing these aspects of new proposals has been recognized for many years by the existence of Technical Development Plans, recently reconstituted and revitalized as the Project Time and Cost Analysis Branch, and Aircraft Production General (Plans). The possibility of combining these branches was considered but rejected in 1963 by the Working Party on Controllerate of Aircraft Planning Services, but we thought it important to re-examine this and to consider whether there should be separate branches with similar functions for aero-engine development and aero-engine production or whether all the analytical work of this type should be concentrated in one specialist branch. In addition, we reviewed possible arrangements in the aircraft equipment fields covered by the Director-General of Civil Aircraft and General Services Research and Development, the Director-General of Aircraft Equipment Research and Development, and the Director of Aircraft Equipment Production.

68. We also looked at possible organizational arrangements for the Controllerate of Guided Weapons and Electronics, since we believe that the need to collect and analyse data on past projects is as great for guided weapons and electronics as it is for airframes and aero-engines. Moreover, there is a higher proportion of Service officers (who, as we have already noted, may never have been concerned with project work before) in the Controllerate of Guided Weapons and Electronics Headquarters Branches than there is in those of the Controllerate of Aircraft. (At 1st September, 1966, the ratio of civilian White Paper Grades to Service officers was 1·7 to 1 in the former, as against approximately 3 to 1 in the latter.) There is no counterpart of PTC(An) in CGWL, though there is a cost analysis section, (Guided Weapons (Production) 3(c)), on the production side, approximating to APG(Plans). In addition, there are project cost sections in the Guided Weapons Research and Development Division, the Electronics Research and Development Division, and the Space Research and Development Division. These have no exact counterpart in the Air Controllerate, though the Executive Officers in the various airframe project branches on the Air Side perform some of the same functions.

69. In theory at least it would be possible at one extreme to have one central analysis branch for the whole of the Ministry of Aviation and at the other for every Director-General to have a separate section under his direct control. Possible intermediate solutions are to have different branches for the two Controllerates and for development and production.

70. The present staffing position is extremely tight and it has proved far from easy to fill the posts already approved, both in the technical branches with whom primary responsibility for the assessment of projects rests, and in branches such as the Project Time and Cost Analysis Branch carrying out analytical advisory work. Greater organizational integration of branches undertaking analytical work is, therefore, likely to make more effective use of the limited staff available. Moreover, it is essential to have a good man at the head of any project analysis branch. People with the necessary specialist expertise and technical background are extremely scarce and it is most unlikely that sufficient could be found for even four branches (that is, separate research and development and production units in each of the two Controllerates). It is also essential that branches should be of reasonable size. If there are a number

of small units, their heads are unlikely in most cases to be above the rank of Principal Scientific Officer or Engineer I, and they will not have the status and authority to be able to deal with the technical branches on level terms.

71. In addition, if the responsibilities for advising on estimates and programmes for the main items within a weapon system are divided between a number of independent branches, not only are different standards likely to be applied, but the interactions between items, which may be appreciable, may not be fully taken into account. Unless there is a considerable measure of centralization, it will be difficult to secure consistency of treatment and approach and to be sure that data from one area can safely be combined with data from another, possibly with the assistance or through the medium of electronic data processing.

72. These considerations point strongly in the direction of one central branch, a view which is given greater strength by the fact that the effort devoted to this type of work in the Controllerate of Guided Weapons and Electronics is very small at present, so that it will be necessary in effect to set up a new branch in that area. The majority of us feel, however, that the creation of one central branch would represent too radical a change in the present organizational structure. We regard it as extremely important that close working relationships should be built up between those responsible for collation and analysis and the technical branches, and we think that this will be better achieved if there is one branch for each Controllerate which will be an integral part of that Controllerate and in no sense an outside adviser or critic.

73. We did not find the arguments for separating analytical work on development programmes and cost from that on production particularly cogent. Although it is true that the present technical and financial organization of the Ministry of Aviation is based on separate branches for development and production, the estimate of unit production cost is often based in the earlier part of a project on the estimate of the cost of manufacturing a development model and sometimes the estimate of the cost of a development model is calculated by factoring up the estimate of production cost. The type of data to be collected and the type of work to be carried out by an analytical branch are essentially the same in both fields and we do not believe it to be sensible to divide the responsibility between two different branches.

74. There would appear to be no difficulty in either Controllerate in creating the necessary links between the technical branches, including project costs sections and their counterparts on the Air Side, and the new branches suggested. In the case of project costs sections, as their task is to keep a record of achievement and of changes in plan as an aid to the management of particular projects rather than to present historical information in their field when a new project is being assessed, their activities are not incompatible with those of the new branch. Indeed, the activities of both are complementary since project costs sections would be the main source from which the analysis branch will obtain its data about both plans and achievement.

75. We have considered the position of the Central Statistics Branch in relation to the proposed new branches. We doubt, however, even if it were decided to create a single central branch rather than the two that most of us favour, whether its functions could be satisfactorily combined with those of the Central Statistics Branch. Although the new analysis branches will need statistical expertise, it is essential that they should be technically based and work in very close co-operation with the technical branches; only in this way will they be able to receive the data and provide the authoritative advisory service that is needed. The Central Statistics Branch on the other hand has much wider non-technical responsibilities. There would therefore seem few advantages and some serious disadvantages in attempting to combine the two. The analysis branches will, however, need to consult the Central Statistics Branch from time to time on such matters as changes in cost levels in the industries concerned.

76. We have also examined the position of the Directorate of Technical Costs. As we have shown, the Directorate's principal experience is in estimating the cost of items when these have been fully defined and we do not believe that they can be expected to make a major contribution to project estimating during the early formative stages of a project when much of the equipment has still to be designed and the full extent of the testing required may not be known. Although the Directorate may have some part to play in checking the estimates of development manufacturing cost and unit production cost put forward at the end of the Project Definition phase that we propose in Chapter 11, we do not consider that there will be any duplication of function between the staff of the Directorate and that of the branches we are recommending.

77. The majority of us recommend, therefore, that separate analysis branches should be created in the Controllerate of Aircraft and the Controllerate of Guided Weapons and Electronics, though a minority favour a single branch serving both Controllerates. We regard the Project Time and Cost Analysis Branch as a first step in this direction. At present, it is concerned primarily with airframes, but we recommend that as soon as the necessary specialist staff can be found, it should become part of a new larger organization which would also cover aero-engines and aircraft equipment, and production as well as development[4]. However, the extent of the contribution that can be made will depend on the availability of suitably analysed past records, and of experienced staff trained to interpret them. It must be some time, therefore, before such a branch can function as effectively as we should like. We are, however, agreed that any new organization formed should act in an advisory capacity and that the primary responsibility for the assessment of programmes and estimates should continue to rest with the technical branches concerned, as at present. The new organization should give priority in its work to those areas where experience has shown that serious increases in cost have occurred most frequently, that is, airframes, aero-engines, and guided weapons. Its activities should, however, embrace the remaining areas from the start and some effort should be reserved for them. Its main contribution would be in the early pre-decision stages of projects, that is, at the Feasibility and Project Definition stages, when it would provide information on the reasonableness of the firm's proposals, in terms of both programmes and cost, in the light of past experience. We envisage not a service of comment on the validity of the estimates made under the individual detailed headings into which we expect the Development Cost Plan to be divided at the end of the fuller Project Definition phase we recommend in Chapter 11, but rather a broader cross-check through an indication of the probable costs of the main constituent systems or areas of work extrapolated from information on comparable systems or areas in past projects.

Data required

78. Any project can be divided into a number of main areas and the level of technical complexity, the technical advances to be made during the project, and the methods of manufacture to be used will vary considerably from one area to another. If the supply Department is to be able to assess contractors' estimates with some assurance, we consider that it will need to have data for each of these main areas in order that cost-estimating relationships can be determined for them.

79. The close delineation of technical areas will enable the degree of technical advance in each to be gauged with some accuracy. Moreover, many areas in a major project are likely to be subject to only slow technical advance, and in any particular new development may be almost directly comparable with a previous project. Attention can then be concentrated on those areas of greater risk and estimating uncertainty.

80. The extent and manner in which a project is sub-divided will, of course, be a matter for consideration with the contractor and will have to take into account his organization and accounting patterns. Nevertheless, if valid comparisons are to be made, a breakdown in some detail will be required since as more areas are amalgamated into compound headings, it becomes increasingly difficult to ensure that like is being compared with like between different projects. Moreover, in order that data from different projects and contractors may be comparable, some standardization of the headings under which returns are made will be necessary so that comparisons can be made between contractors within any one field and as much as possible between fields. However, we accept that in the early stages of development, until sufficient project definition has been achieved, some amalgamation of headings may be unavoidable.

81. The information required is much the same as that required for effective monitoring of a project, and we propose that it should be collected, in the main, from the returns required from contractors for project management. These returns must in turn be related to the Development Cost Plan headings so that expenditure can be compared directly with estimate. Appendix I gives the information on development programmes which a pilot investigation suggests should be recorded in the airframe field. We do not regard this as necessarily definitive, but we include it as an indication of the sort of information that is needed.

82. However, a record of expenditure without a knowledge of related physical progress is of little value either in monitoring the project or for giving useful data against which to compare future programmes. It is important, therefore, that from an early stage, at least an outline PERT network should be drawn up, or comparable information be provided, in sufficient detail to enable it to be used as a measure against which progress can be judged and from which significant milestones can be derived. The activities within such a network should be related to headings in the Development Cost Plan and the latter, in turn, to items in the contract.

83. It has been evident from our studies that in the past the activities or events in the programme or PERT network, the headings in the Development Cost Plan, the items in the contract schedule, the data on technical progress, and the divisions in the returns of expenditure have not always been prepared in a form which allowed a meaningful comparison between them. We attach considerable importance to the need for this and consider that greater co-operation is required between technical, finance, and contract branches in the early stages of the project to ensure that the contract schedule, the development programme and cost plan, and the manhour, cost, and progress returns are all mutually consistent and so arranged as to assist the effective monitoring and control of the project. In this connection, we would stress that the views of the firm must also be taken into account so that the items chosen for these documents are consistent with its estimating, cost collection, and control procedures.

84. If sufficient use is to be made of previous experience, it is necessary to know why past programmes have changed throughout the life of a project and how these changes have, in turn, reflected on effort and cost. It is important, therefore, that the successive development plans and estimates should be available on all major projects. These should be supported by copies of the Staff Requirement and the specification, together with their amendments. We regard project diaries, which would include notes of significant achievements and setbacks, major policy decisions, and all necessary file references, as very valuable documents which should be kept for all major projects and should be readily accessible. Without documentation of this sort, it is impossible to define the relation of actual expenditure to the estimates, or to assess the likely effects which changes in requirement, or changes in the technical situation, may have on a new project.

85. A possible source of information about past projects which we have not examined is the records in the Directorate of Technical Costs. Although information may exist there which could contribute to better cost estimating, for development as well as production, it may not be in a form in which it can readily be used for this purpose. We suggest, therefore, that one of the tasks of any expanded project analysis organization should be to investigate what information exists and whether any use can be made of any of the Directorate's past records for assessing programmes or the forward estimates of project costs. The need for information related to physical areas of a project should also be borne in mind in any future scheme to re-organize the Directorate's records.

86. There is an important additional difficulty in building up estimating relationships for production. This stems from the fact that, although in the main development contracts are priced on a basis related to actual costs and the actual costs of a project should, therefore, be available to the Ministry of Aviation, production contracts are normally placed either at 'prices to be agreed' or at fixed prices. In almost every case a fixed price is agreed well before the end of production. This means that the actual costs do not become available to the Ministry.

87. The Government has accepted the recommendation of the Second Lang Report[5] that, as a safeguard against the payment of excessive prices, there should be equality of information between a Department and its contractors up to the time prices are fixed. The Government further believes that post costing, which provides knowledge of the out-turn of completed contracts, is an essential part of equality of information. Information obtained in the future by the Department as a result of equality of information and post costing may prove to be of considerable value in analysis work.

Overhead rates in Development Cost Plans

88. We have already referred to the large proportion of total costs that is often accounted for by overheads. This means that changes in overhead rates can be an important reason for changes in total costs and led us to reconsider the present practice of requiring contractors to use in their forward estimates the most recent overhead rates agreed with the Contracts Division, or with the Directorate of Accountancy Services, subject to the final approval of the Contracts Division. The figures of overhead rates over ten years for thirteen important contractors, which were given to us by the Directorate, did not reveal any general trends. Thus, although one of the effects of technological advance is often an increase in costs normally allocated to overheads and a reduction in costs charged direct, there are other factors, such as changes in the level of activity, variations in capital investment allowances, and the effects of company re-organizations, which may work in the other direction. The present practice is basically sound provided contractors are also asked for their estimate of what the actual rates for the present year and future years will prove to be.

89. There is, however, one improvement which we think should be made. Under the present arrangements, overhead rates for any individual contractor are not agreed by the Ministry of Aviation until at least six months after the end of that contractor's financial year. In some cases they are not agreed for a considerable period after that. As a result the last agreed rates may be somewhat out-of-date. We therefore recommend that where a contractor prepares for his own purposes budget rates for Ministry work, he should use these in his cost plans for those periods up to and including the current year for which rates have not yet been provisionally or finally agreed with the supply Department. He should also use the current year's budget rates for all future years, again with the qualification that he should be asked in addition to give separate estimates of the rates for future years if he expects these to be different from the current year's rates.

Responsibility for monitoring overhead rates

90. The potential consequences of movements in overhead costs also led us to enquire into the arrangements for considering whether the total overhead costs of a contractor were reasonable in relation to his total direct costs. If a contractor has obtained a large volume of civil work under competitive conditions, it may fairly be argued that market forces will ensure that his overhead costs do not rise too high. The supply Department's review in such cases can therefore be confined to ensuring that its contracts bear an appropriate share of total overheads and no more. In a number of important cases, however, firms are almost entirely dependent on Government contracts in a field where there is little or no competition, and in these circumstances ordinary market forces have only a limited effect. It is important that all branches should realize that, in these cases, they have a special responsibility for monitoring those aspects of the work which contribute towards overhead costs. There is some evidence that technical branches tend to regard this as being entirely the concern of the Directorate of Accountancy Services and the Directorate of Technical Costs, who do indeed devote a significant part of their effort to this task. It should be more generally realized, however, that this is a common responsibility affecting all branches supervising the work undertaken by firms on Ministry contracts. Technical branches should, therefore, concern themselves with the efficiency of contractors' management both overall and at departmental level and should raise with both the contractor and with the two Directorates any instances where inefficiency appears to be making overhead costs higher than they need be.

91. At some contractors, overhead rates are very high. This can be caused by the way costs are allocated between direct and overheads by the firm. This is particularly the case in the aero-engine field where it has been the practice to charge design costs to overheads. This hinders the proper estimation and control of development costs and we were glad to learn that the Contracts Division is very active in trying to secure a change in the basis of allocation of costs so that a greater proportion is charged direct. We entirely support the action they are taking. In the cases where overhead rates are high because the direct labour base is narrow, technical branches need to exercise particular care over the authorization of work which will be charged direct since the total cost of such work may be out of all proportion to its value.

REFERENCES

1. Report of the Working Party on the Directorate of Technical Costs, July, 1964, Appendix A.
2. Op. cit. paragraph 30.
3. Op. cit. paragraphs 37 and 38.
4. While this report was being prepared responsibility for the development and production of air armament and air navigation and reconnaissance equipment was transferred from the Controller of Aircraft to the Controller of Guided Weapons and Electronics. This transfer of responsibility underlines the need for close co-operation between the two branches the majority of us recommend since analysis work in these areas will now become the concern of the proposed new CGWL branch.
5. HMSO Cmnd. 2581 of February 1965, Second Report of the Inquiry into the Pricing of Ministry of Aviation Contracts.

CHAPTER 6

The External Studies

The auditors' reports

92. By the middle of 1962, the main provisions of the new Ministry of Aviation procedures for the authorization and control of development projects had been introduced. Attention was then directed towards the systems of financial control (including the preparation of forward estimates) used by the Ministry's principal contractors on contracts to be priced by reference to actual costs since if these were inadequate, the effectiveness of the new procedures would be gravely at risk. Accordingly, in August, 1962, the then Under-Secretary (Contracts) invited forty-three contractors to arrange for their auditors to review and report on the salient features of their systems of financial control.

93. In particular, it was suggested that the auditors' reports should indicate:

(a) whether the methods of co-ordinating and evaluating forward estimates of the time of operatives and staff, consumption of materials, use of facilities, etc., afforded reasonable assurance that the whole of the financial implications had been taken into account;

(b) whether the estimates were prepared on the basis of an allocation of costs corresponding in detail to that currently used to ascertain and record the costs actually incurred;

(c) whether the estimates were analysed to correspond to the timephasing of the programme of (expected) work, so that the forecast costs and dates of completion were shown for reasonable groupings of tasks to be performed;

(d) whether the actual costs were recorded regularly and promptly so that comparisons could be made readily with the relative parts of the estimate, as regards both costs actually incurred (including work sub-contracted, but not yet billed or paid for) and the physical progress of the work; and

(e) whether such records were kept resonably up-to-date; whether the comparisons were made as a routine; whether the effect of significant variations was assessed and reported promptly to the appropriate levels of management.

94. The original forty-three companies were reduced by agreement to thirty-seven and a list of these companies is at Appendix J. Each auditors' report was followed up by the Ministry's Directorate of Accountancy Services with the company or its auditors, or both, and by August, 1964, (when we came to consider how best to carry out the industrial aspects of our enquiries), action on twenty-three had been completed. Work on the remaining fourteen continued and the exercise finally came to an end in February, 1966, apart from two cases where a further examination by the Directorate was still to take place.

95. The conclusions which emerged from this exercise are recorded in sub-paragraphs corresponding to those in paragraph 93. Where appropriate, our comments are given in square brackets at the end of the sub-paragraph:

(a) all the reports from the firms' auditors gave a general assurance that each company's estimating procedure made financial provision for all the technical implications of a particular project *which were foreseen at the time of preparing the estimate.* [This last qualification is of great importance since it has been demonstrated many times in recent years that all the implications may not be seen at this point. In fact they may not be recognised for some long time afterwards even where feasibility followed by project studies are undertaken and supporting Development Cost Plans are prepared. Contractors make some provision for specific difficulties in particular areas on the basis of past experience, but these have often proved grossly inadequate. Moreover, it has often been impossible to foresee all the areas in which trouble might arise];

(b) the basis of preparing estimates was generally found to be compatible with that for recording costs, but there were indications that estimates were being prepared in greater detail than was easily and readily available from the cost accounting system;

(c) contractors found it most difficult to analyse estimates so that the time, cost, and performance, as planned for separate parcels of work or areas of effort, were identified. At the time of the auditors' review all the major contractors had had some experience of the Development Cost Plan procedure and thus they had had to some extent to meet this requirement. Nevertheless, the Ministry of Aviation's accountants found, during the early part of the exercise, several instances where this experience was limited. In some cases it was alleged that the very nature of a development programme precluded the setting of short-term mile-stones of achievement in specified areas of effort;

(d) & (e) in general the auditors' review showed that the procedures followed on the recording of actual costs had been adequate, but the Ministry's accountants noted two common deficiencies. Firstly, some contractors had virtually no records of outstanding commitments, although there was general acceptance of the need for such records. Secondly, the validity of the comparisons made depended to a greater or lesser extent on a subjective assessment of technical progress rather than on the ascertained achievement of defined events. Considerable difficulty would seem to have been experienced in breaking down a large development programme into relatively short-term tasks, or groups of tasks, so that any return of costs would automatically show whether the programme was (in detail or overall) in line with the plan. When effort stretched over a protracted period and progress had to be assessed at intermediate dates the difficulties were increased.

96. The results of these investigations showed that, whatever the reasons may have been, the systems of cost estimation and cost control at aircraft equipment and electrical and electronic contractors were generally more satisfactory than those at aero-engine and aircraft companies. Although there was evidence that the latter group was improving, many of the systems used in the aero-engine companies and in parts of the aircraft companies needed stengthening. Nevertheless, it was encouraging that in almost every company examined consideration was being given to, or action was being taken on, further changes to improve the situation.

97. In the light of this changing situation, we consider it desirable that, before placing any new major development contract, the supply Department should look again at the selected company's proposed system of control in order to be sure that the requirements of an effective system have been introduced, consistent with the estimating, budgeting, and cost collection procedures recommended in the Handbook of Procedures to which we refer below. We also recommend that where the supply Department is doing continuing major business with a contractor, his financial and accounting system should be checked at regular intervals, say, every five years.

The consultants' industrial case studies

98. Because of the changing situation revealed by the auditors' reports, we commissioned two firms of management consultants to establish the present procedures used in industry for preparing technical programmes of development work, estimating the cost of such programmes, and controlling work in accordance with the approved technical programmes and cost plans. We considered this to be important, because to the extent that the methods used in industry are unsatisfactory, the supply Department's procedures are bound to fail in their main purpose. Between May 1965 and March 1966, the two firms of consultants, Associated Industrial Consultants Ltd., and P.A. Management Consultants Ltd., studied twelve projects involving some of the principal contractors of the Ministry of Aviation. Their terms of reference and a list of the contractors and the projects they investigated have already been given in Appendices D and E.

99. We selected the projects to cover as wide a range of the Ministry's principal contractors and fields of activity as possible and the estimated development cost of the projects at the individual contractors varied from less than £0·5M to over £70M. We also attempted in our selection to reconcile two conflicting requirements: that projects should be sufficiently recent

to ensure that the latest methods were being studied; and that development should have proceeded sufficiently far to enable a valid comparison to be made of progress against plan. All the projects studied were the subject of contracts which were to be priced by reference to actual costs.

100. The consultants submitted reports to us at the end of each case study and when all had been completed, we commissioned them, jointly to summarize the statements of fact which they had agreed with the contractors and their comments and conclusions. Their summary of the agreed statements of fact is reproduced as Appendix K. Finally, the experience which the consultants had gained led us to ask them to draw up a set of integrated procedures for programming, estimating and control on future defence development projects. The Handbook of Procedures at Appendix M which they have prepared as a result, in conjunction with ourselves, is intended to serve as a guide both to contractors and supply Department technical branches. The procedures suggested are based on best current practice and everything that is proposed is similar in principle to what is already being carried out by one or more of the Ministry of Aviation's major defence contractors.

101. In the remaining paragraphs of this chapter, we describe the main features shown by the consultants' studies to be most in need of improvement either in the Ministry of Aviation or in industry. These paragraphs have been agreed with the consultants as a fair representation of their views on the position. It should be noted, however, that they record the position as seen by the consultants, who have not looked in depth at procedures, or at the conduct of specific projects within the Ministry of Aviation, although they have given attention to the inter-face between the Ministry and its contractors. Statements in the following paragraphs in this chapter, or in the summary of agreed statements of fact at Appendix K, relating to particular Ministry of Aviation or Ministry of Defence activities should not, therefore, be taken as necessarily having been accepted by the Ministries concerned in all cases. Nevertheless, although we might dissent on particular points in the consultants' findings, we are in broad agreement with them about the improvements that are required both in industry and the Ministry of Aviation or its successor. We have already noted and made recommendations in Chapter 5 as a result of our own studies on the need, confirmed by the consultants' investigations, for a more disciplined and professional approach to project assessment and management within the Ministry. The further action that we recommend both in industry and in the Ministry of Aviation or its successor is dealt with in later chapters of this Report and in the Handbook of Procedures which translates our conclusions into the detailed procedures we believe to be necessary.

Summary of the consultants' findings

102. **The state of definition at the end of the project study.** No contractor can be expected to prepare an adequate Development Cost Plan unless he is given a clear and detailed statement of the requirement he has to meet. This normally takes the form of a Staff Requirement or of a Ministry of Aviation technical requirements specification, that is, a statement in technical terms of the ends to be achieved. In rather more than half the cases examined, the contractors considered the definition of the requirement to be generally adequate, but those where the definition was thought unsatisfactory included three of the most costly developments. This is unsatisfactory and underlines the need in such cases for more rigorous attempts by the user Department, in consultation with the supply Department, to establish clear requirements in adequate detail before development projects are put in hand. Unless the main parameters of performance and design are established at an early stage, the engineering proposals emerging at the end of the project study, together with the time and cost estimates based on them, are bound to be suspect.

103. In many of the cases studied the formal project study was of an abbreviated form or did not exist at all. Thus, although most of the projects went through a stage of design or project study, and a design specification, that is a description of the technical means proposed to meet the stated objectives, was issued at the end of the study stage (or equivalent period of time), in no case was an adequate specification produced at this point; if indeed such a specification was possible as large technical uncertainties still remained owing to the brevity and narrowness of the studies. As a result, no satisfactory basis existed for a realistic development programme and cost plan; those which were prepared were too broad for the subsequent effective control of technical and cost progress and for the evaluation of any later changes

which might be proposed, and the absence of detailed specifications allowed different assumptions to be made by firms and the Ministry on the work which the programmes and estimates were intended to cover. In addition, programmes and estimates were often unduly influenced by technical and commercial optimism.

104. The picture which emerges is that projects were approved for full development before sufficient work had been done to reduce the major technical uncertainties to the extent necessary to achieve a reasonable degree of estimating accuracy. Although the period needed to reach this point varied with the type of project and the technological advance involved, it appears from the cases studied that a period of up to about 25% of the total estimated development time might be required at a cost of up to about 15% of the estimated total development cost.

105. It is important that early agreement should be reached between the supply Department and the contractor on the extent of the work to be undertaken during this exploratory stage; on the division of the total programme into its main constituent parts; on the breakdown of costs to be shown for each part; and on the time periods for which separate estimates should be given. Moreover, the supply Department should be in sufficiently close touch with the contractor throughout his study to advise him, in conjunction with the user Department as necessary, on 'trade-off' investigations and to indicate, should substantial reductions in cost appear possible, what relaxations in technical standards or performance might be acceptable. For these purposes, much closer and more effective co-operation between the supply Department and the contractor is needed during the project study stage.

106. **Programming.** All contractors began programming by making broad assessments of the time required to complete major stages of the project, but there was considerable variation in the extent to which attempts were made to draw up more detailed programmes within each major stage and to use these to validate, and if necessary to amend, the original broad appraisals. In general the degree of detailed programming in the early stages of projects was inadequate for proper planning and subsequent control.

107. All contractors revised their programmes as work proceeded and as revised Development Cost Plans were required by the Ministry of Aviation. Some contractors prepared revised programmes only at the time of Development Cost Plan submissions, others revised them more frequently and simply put in the latest edition whenever a revised Development Cost Plan was required. In some cases revised programmes were simply revised broad appraisals of the total time required for each major stage, in others the improvements in technical definition were used to refine detailed programmes and hence to revise the overall programme.

108. About half the contractors expressed programmes in the form of bar charts and about half refined broad programming by the introduction of PERT/Time. Most of the contractors were conscious of the limitations of bar charts and of the theoretical advantages of PERT, but several had met difficulties in its practical application. The main difficulty seemed to be the shortage of trained staff to construct and operate the networks: difficulties were also experienced in co-ordinating between different functional departments in a company the remedial action required as a result of PERT predicted events.

109. The organizational arrangements varied considerably between contractors. There is some evidence, however, especially when PERT is being used, that a central programming unit reporting to a senior executive is the most effective arrangement. This unit, which may either provide a service to the line management or have executive authority in its own right, may also be concerned with estimating and the release of budgets and with the preparation of reports on technical and cost progress.

110. **Development cost estimating.** In four cases, all in the electronics field, the contractors attempted during the project study to build up a total development cost from a consideration of individual tasks within the overall project. In the other eight cases estimating was limited to broad areas of work within the assumed timescale. All those contractors who had been working on their projects for some time had submitted revisions of their estimates at not more than annual intervals and most prepared estimates in greater detail as knowledge increased and technical uncertainties were resolved.

111. Development Cost Plan submissions varied widely in the details and methods of presentation. Many of the cost plan aspects could have been improved, for example, by firm direction from the Ministry of Aviation on the split of cost estimates required and the items or areas of work to be shown separately. The more informative estimates were those submitted by some electronic firms on a proforma devised by the Project Costs Section of the Electronics Research and Development Division. These showed the costs for each contract item, divided into salaries and wages, materials, sub-contracts, overheads, and profit, quarterly for the first year, half-yearly for the second year, and annually thereafter. At the other end of the scale one contractor submitted only estimates of total cost for each of four large areas of work, arbitrarily allocated to individual years.

112. Many of the estimates prepared were unduly dependent on personal experience and judgment and the need for more and better analysed data from past projects was also evident. The more progressive contractors have already appreciated this and try to use background information from previous projects within their own organizations. This lack of objectivity applied particularly to some of the early estimates, including those put forward at the end of the project study. In some cases, the Ministry of Aviation's failure to allow sufficient time—only five weeks in the case of one major project—made the task of preparing estimates more difficult, and this, together with technical uncertainties and the commercial pressures towards over-optimism, prevented a proper appreciation of the real magnitude of the task from emerging. If more work were carried out before a substantive Development Cost Plan was required some improvement in the standard of estimating could fairly be expected as a result of better technical definition and more detailed programme formulation.

113. The estimating procedures of the aero-engine companies incorporated a major weakness of their accounting systems. (This has already been referred to in paragraph 91.) In both cases staff who could properly have been regarded as a direct charge were included in overheads, with the result that unnecessarily large overhead rates were established. This method is unsatisfactory for the proper estimation and control of cost on complex development projects.

114. **Monitoring and controlling technical progress.** Nearly all the contractors made some effort to prepare operating programmes consistent with the overall timescale by dividing the work into tasks represented either by bars on a bar chart or activities in a network. The effectiveness of these programmes as a basis for monitoring and controlling technical progress depended on the fineness and realism of the task breakdown and on the frequency of clearly identifiable milestones or events. The use of networks generally provided a realistic basis for technical monitoring, though when PERT was used its initial application was delayed on many of the projects seen and it suffered from the deficiencies in its application which have already been referred to in paragraph 108. Where bar charts were used the individual tasks tended to be too large and the milestones too far apart to allow prompt detection of actual and potential deviations from programme.

115. All contractors relied on informal contact between managers and supervisors at the working level for the day-to-day monitoring and control of technical progress. One contractor relied exclusively on this method, which proved adequate in the circumstances because the project was small and the organization carrying it out was based on the product under development rather than on functional departments serving a number of projects. In the other eleven projects informal monitoring was supplemented by formal meetings between work supervisors and middle management and between middle and senior management. These meetings were generally held at least once a month and in most cases a formal written report or PERT print-out was circulated in advance.

116. In ten projects contractors submitted written reports on technical progress to the Ministry of Aviation at not more than quarterly intervals. These reports formed the basis for discussions at formal progress meetings with the contractors. These formal contacts were supplemented by frequent informal consultations.

117. **Monitoring and controlling cost progress.** In the twelve projects investigated only one contractor had procedures for monitoring and controlling cost progress adequately integrated with those for monitoring and controlling technical achievement. In this project the broad aim was to divide the total project into a large number of discrete tasks. At the time of the

investigation not all the major tasks had been broken down in this way, but the procedures were being continuously extended with the intention of applying them to all areas of the project. A budget was set for each task which was consistent with the total estimate, and the cost collection procedures enabled actual costs to be reported and compared with budget in some detail. The time lag between the end of an accounting period and the presentation of reports was usually about two weeks. The responsibility for the management and control of each task in terms of cost, time, and technical performance within an agreed budget was delegated to one man although, as he was obliged to draw on departmental resources, he did not have full authority for all aspects of the task.

118. All but one of the remaining contractors operated a system of internal management accounting which reported expenditure against budgets by functional areas of the organization. These systems did not always provide a means of monitoring costs on individual projects and in these cases other procedures had had to be established for this purpose. The effectiveness of these procedures tended to be determined by the extent to which the project was divided into individual areas of work to which budgets were applied. The most common method was to use the work breakdown and estimated expenditure in the Development Cost Plan for the preparation of monthly or quarterly budgets. In most cases the resulting reports were of limited value to management because they were only for comparatively large areas of work and were not correlated with tasks in the technical programme. The actual or potential costs of programme deviations were not, therefore, easy to identify.

119. Speed of presentation of cost information varied considerably. Two contractors had information available to management within ten days of the end of a period. Six contractors did not have information available in less than four weeks and in two of these the average time was six to eight weeks. Delays of as much as four weeks must gravely undermine the effectiveness of any cost control system and a drive is needed in many of the companies seen to accelerate the preparation of financial reports. It is significant that in the companies where cost control has been given most attention, the criterion of speed has been more than achieved, for example, in one case data was available to management within seven days. This confirms the view that, given determination on the part of the contractors to establish the mechanisms, there are no real procedural difficulties to meaningful cost control. It requires the availability of data processing services and, in the larger firms, a computer, but this is not an unrealistic requirement for contractors operating in this field.

120. It is clear from the preceding paragraphs that many contractors are unable to monitor and control progress in the depth of detail that is necessary for efficient operation. Whilst considerable efforts have been made in certain areas to improve procedures to provide a better correlation between technical and cost progress, further and more general improvement is necessary.

121. **Production cost estimating.** On several of the projects investigated, the Ministry of Aviation had approved development without receiving any formal production cost estimate from the contractor. Although production cost estimates are likely to be unreliable in the early stages of a project, particularly if they are made before sufficient depth of study has been done to define fully the engineering characteristics of the equipment, nevertheless, the Ministry should have requested unit production cost estimates before authorizing full development. Unit production cost should be one of the controlling factors during development, particularly on projects where the total cost of production is likely to be large, and, wherever possible, the Ministry should give the contractor a production cost aim. (This is dealt with in more detail in Chapter 7.)

122. Accurate estimates of production cost can only be expected when development is well advanced and full drawings are available, but enough detail should be available after an adequate period of project definition for the preparation of reasonably well-founded estimates. Only a few contractors appeared to have adequate arrangements for this and in a number of cases the unit production cost had risen substantially although development was by no means complete and the Staff Requirement had remained substantially unchanged.

123. **Records linking performance or technical characteristics with cost.** In three cases contractors relied upon statistical or parametric extrapolations from the results of past projects when making their development cost estimates. These contractors, who came from quite

different fields of technical activity, argued that, until development had progressed far enough to enable the equipment to be defined in some detail, only this type of estimating was valid. The remaining contractors were distrustful of this method and none of them used formal extrapolation from historical records when estimating development cost. A common argument was that the number of relevant previous projects was often very small and that in any case techniques, materials, and processes changed so much from one project to another that comparisons were bound to be misleading. As a result their assessments were often based on personal judgment. In the electronic field it was argued that rapid technological advance, for example, from valves to printed circuits to transistors, made the projection of historical trends dangerously misleading. However, most contractors had fewer inhibitions about using data from past projects for estimating production costs and nearly all kept records for this purpose. Four of the these had analysed costs to give a predictable relationship with the production costs for new products, using various common factors as a parameter.

124. Although experience from past projects must be used with considerable caution, well-kept records, suitably analysed, have an essential part to play in estimating both for development and for production. In some cases, they can provide a salutary check on the natural optimism of many development engineers.

125. **Value Engineering.** In none of the twelve cases was Value Engineering, (here defined as a formalized effort directed towards analysing the function of defence equipment with the purpose of achieving the required function at the lowest overall cost), being applied fully and to the whole equipment being developed, with the intention of obtaining the lowest combined development and total production costs. However, in half the cases, Value Engineering techniques were being applied to small selected parts of the equipment or formal cost reduction activities had been or were being carried out by special teams employing some Value Engineering techniques, but not the full methodology. In two cases contractors made no claim to be undertaking any formal cost reduction activities and maintained that cost must be secondary to performance considerations.

126. Despite the limitation on its application, staff on all but three of the projects were enthusiastic about Value Engineering as an idea. In some firms engineers and designers had been on training courses and were familiar with the basic principles and techniques. Contractors' managements often expressed the hope that 'cost-consciousness' inculcated by such training would result in the men producing lower-cost designs, but it was not possible to check whether this hope was being fulfilled. Some contractors gave no Value Engineering training to design or other staff, and had no formal method of promoting cost-consciousness. These firms believed that competent engineers will pay sufficient attention to value without any specific training or encouragement.

127. **Design changes.** Once drawings had been 'frozen' for production, all contractors expected to have to comply with Ministry of Aviation procedures for amendments and modifications to the design. Before this point practice varied. In some cases, formal procedures, covering all or part of the equipment being developed, were used to consider the effect of the proposed changes. In others, procedures were informal. Procedures were not, however, sufficiently rigorous to prevent the introduction of changes which were desirable rather than essential, nor were the effects on cost examined and evaluated in a critical enough manner. These deficiencies stemmed from the lack of a breakdown of the project into reasonably sized, clearly defined tasks with appropriate time and cost budgets. It is essential that, if design changes are to be monitored and control exercised, an adequate datum for these functions is provided. A breakdown to tasks each with its own specification and budget would allow this to be done.

128. **Contract aspects and project delays.** In a number of cases there was delay between the project study and full development. Some projects were kept going by holding contracts, but these latter were of low value and did not allow work to proceed at the rate which had been planned. As a result, these projects lost momentum and contractors complained that there was a serious deterioration of morale and that, in some cases, key team members were lost.

129. A number of projects continued on holding contracts into the main design phase and much uncertainty was generated because work was authorized in very short periods, typically

of two to three months each, which had to be extended repeatedly. One project which continued on this basis for forty-eight months was without contract cover on no less than thirty-four occasions.

130. **Conclusions.** The main lessons from these studies for the supply Department are that they show very clearly the need:

(a) to obtain a clear Staff Requirement covering all aspects of the project before commissioning a project study; and

(b) to ensure that the contractor is given adequate time, finance, and guidance to enable him to draw up a first comprehensive engineering and trials specification which he can then use to prepare a well-considered programme and cost plan. Part of that cost plan should be a first indication of the likely unit production cost of the final equipment, evolved, in an objective and systematic manner, from a synthesis of the constituent part of the design.

131. On the industrial side, the studies showed a wide variation between contractors. However, better appreciation of the need for rigorous project cost control existed in those companies in which Ministry of Aviation costed contracts constituted only part of their development activities. Contractors whose methods were above-average in one area, for example, programming, were sometimes below average in another, for example, cost collection. The technical reputation of firms was not necessarily matched by the quality of the project management procedures employed. In addition, during their early stages, projects were hampered by the short-term contract arrangements which prevented the orderly building-up of effort necessary to achieve a smooth transition from project study to full development. The main weaknesses which were found were essentially concerned with the detail to which programming, estimating, and monitoring were taken, and with the lack of a sufficiently close and defined relationship between individual areas of work and their cost. Thus in many cases there was a lack of detailed work programmes for the various aspects and phases of the total project, and estimates were made for broad areas only. In consequence, it was difficult to set financial budgets for the achievement of the various steps in the programme, and technical progress and cost could not be monitored with the precision necessary to give early warning of actual or potential deviations from programme or estimate. In some cases the issue of cost reports was greatly delayed and this reduced whatever value they might have had for control purposes.

132. If a realistic programme and estimate is to be prepared and control is to be effective, the total project must be divided into a number of discrete tasks. On a large project the number of tasks may run into many hundreds. The responsibility for each task must be assigned to one man, an estimate must be prepared, and a date and financial budget set for its completion. Regular reports must be available promptly on a task-by-task basis to check technical achievement against plan and the related cost against budget.

133. After design and engineering uncertainties have been reduced by a period of project definition, and a design has been established, it is important that only properly considered and authorized changes to the project are implemented. For this, the use of a design change procedure (in advance of the introduction of formal modification procedure) is valuable, both for the contractor and the supply Department, and a breakdown of a project into tasks, as proposed, is also necessary to provide the datum to which changes can be related.

CHAPTER 7

The Working of the Present Procedures

Implementation of the present procedures

134. The Ministry of Aviation's internal instructions on the procedures for the control of research and development are set out in a number of Notices issued by the Controller of Aircraft and the Contoller of Guided Weapons and Electronics. The more important of these are listed in Appendix L. Chapter 5 of the Ministry's Finance Handbook is also relevant. These are supplemented in some areas by individual branch instructions on the format and content of Development Cost Plans and on the subsequent technical and financial returns to be made by contractors during development. These instructions vary from one area of technical activity to another. In all cases, however, it has been the intention that proposals for the development to completion of all major and large minor projects should not be considered for approval until a project study has been carried out.

135. Although the feasibility of projects has in general been examined in accordance with the intentions of the Zuckerman Report[1], the distinction between the feasibility[2] and project study[3] stages has not always been maintained as clearly as was envisaged. Moreover, it is evident that in the great majority of cases project studies have not been carried out with sufficient thoroughness and in accordance with the Zuckerman proposals: not only has the project study been both shorter and less costly, often substantially so, than was envisaged; it has also been more superficial. Indeed, in a number of areas, it has become a convention that a project study should be limited to theoretical work and that little or no experimental work or laboratory trials should be included. As a result the extent of the work undertaken during the project study has amounted in many cases to little more than was intended should be undertaken during the feasibility study stage.

136. There has probably been a number of reasons for this. In some cases, the prospect of international collaboration or the belief that a particular in-Service date would not otherwise be achieved or the need to maintain an even load of work on a particular firm or group of firms has resulted in decisions being taken before the results of a proper study were available. In other cases, although the instructions issued within the Ministry of Aviation stress the importance of a properly prepared Development Cost Plan, the lack of a definitive document on the proper technical content of a project study may have contributed to a failure to appreciate what was intended, with the result that insufficient work was authorized. In still other cases, the contractor has lacked understanding of the purpose of a project study or made his own assumption of the cost that the Ministry was likely to be prepared to bear for such a study, and has limited his work or his proposals accordingly. He may also have been influenced by a desire to get approval for full development as early as possible because his resources were becoming under-utilised. Whatever the reason, in the great majority of projects investigated, the time and effort put into the project studies have been substantially less than the 5% of the then estimated cost of the project suggested in the Zuckerman Report[4]; moreover, as the final cost has always tended, sometimes grossly, to exceed the initial estimate, the real position has been even worse.

Factors leading to under-estimating

137. One important factor which has emerged is that in the formative stages of a number of projects firms have adopted what appears to have been a deliberately over-optimistic attitude, and have submitted estimates which made wholly inadequate allowances for the cost of overcoming the many problems that must be expected to arise during a development programme. The tendency for firms to under-estimate has been encouraged in some cases by the Ministry of Aviation's practice of inviting a number of firms to submit competitive design proposals. This practice involves no financial risk for the contractor since the terms of the development contracts have still to be negotiated and it is usually necessary to place development contracts on the basis that the contractor will be paid his ascertained costs and a sum to be agreed for profit. It has been defended on the ground that a realistic estimate might result in a worthwhile project being abandoned prematurely[5] or in the work being awarded to a more optimistic competitor; and it appears to be widely believed in industry that estimates which start at a low figure and rise gradually over the years as development proceeds have a

greater chance of acceptance than those which are realistic from the start. In consequence, the technical programmes and estimates of cost, on which decisions whether to proceed with full development have been based, have been more sketchy and much less reliable than was the intention when the project study stage was first introduced.

138. In addition to evidence of pressures within industry to keep estimates down to a level which it is believed the Ministry of Aviation will be likely to accept, there appears to be reluctance within the Ministry to add allowances of the magnitude that past experience might suggest is necessary. One of the reasons for this is the widely held belief that costs tend to rise to meet the approved estimate or the money believed to be available. According to this view, if a high estimate is accepted from a contractor, costs will also be high; whereas if a low estimate is accepted, costs will rise but will still turn out lower than they would have done if a higher estimate had been accepted in the first place. While we recognise that efforts to keep estimates down may be a necessary element in cost control, they must not be allowed to lead to the preparation of unrealistic programmes and estimates by contractors, still less to their acceptance by the supply Department. However, under present conditions, neither technical branches nor finance branches are in a strong position. Lacking authoritative guidance based on proper records of past programmes and costs and an adequate organization to collate and analyse them, technical branches are uneasily aware that any assessment of project costs depends very much on personal judgment and the interpretation put on past experience by whoever is making the assessment and that they are not well placed to sustain convincing arguments in favour of a particular level of expenditure. Finance branches, having no technical knowledge, are in an even weaker position. Neither of these branches is in consequence able to refute, convincingly, arguments that a Development Cost Plan already takes account of past experience, is more realistically based than its predecessors, and that in consequence the addition of further allowances or a large contingency margin is unnecessary and is likely only to invite additional costs, which would otherwise be restrained. As a result the official estimate eventually put forward may be a compromise on the lowest figure on which it is possible to reach general agreement rather than one based on an objective study of the facts, taking proper account of the lessons of experience.

139. Nevertheless, there is evidence that as a result of the efforts that have been made in recent years, there has been some improvement in the quality of the estimates on which decisions to authorize development have been based and we believe that further improvement can be secured by the more detailed analysis of programmes into their constituent tasks. This, if properly carried out, should help substantially to improve estimation and the definition achieved should provide a basis on which subsequent proposed changes to the programme can be assessed. We believe that the discipline which the need to justify such changes will impose will provide a useful counter to any tendency for programmes to increase in elaboration in accordance with the funds which it is believed can be made available. We deal with this further in Chapter 11.

Limitations of estimates arising from project studies

140. However, even if the existing procedures were to be implemented more fully, and studies were to be conducted to the depth envisaged in the Zuckerman Report, the estimates arising at the end of the project study stage would still be liable to fairly wide margins of error, particularly if the project involved areas of above average technical risk. Moreover, they could not be used effectively for a detailed comparison of actual out-turn with planned achievement. This is because the estimates at this stage are prepared on the basis of a general concept of what the weapon or equipment will be like and are arrived at essentially by analogy with past or current experience of other projects in the same field. As the consultants' studies have revealed, a much more detailed study of the development problems and the tasks to be undertaken is needed before a well-founded programme can be established. This requires identification of the tasks in some detail and of the problem areas. Assumptions may have to be made in these areas about the probable nature of the tasks and their content, even though these may have to be modified as a result of later development, so that a sound basis may be provided for the evaluation of subsequent changes and costs. By these means a development programme can be prepared in which the content and sequence of events can be planned in detail (making adequate allowances for redesign, rework, and retest), the cost of successive activities estimated, and the whole summated.

141. It is against this background that we have sought to obtain a more explicit understanding of the processes of estimating for advanced development and, on that basis, to formulate new principles to govern the decision making procedures.

Types of estimate

142. It is necessary first to analyse the various methods of assessing the likely cost of development which hitherto have been collectively and indiscriminately termed 'estimates', and to identify the stage in the project at which each method is mainly applied. In practice, however, the distinction between the methods and the points in time at which they are mainly used is not as sharp as it may appear on paper. Although estimates will be prepared using different methods at different times, different methods may be used for the various parts of one total estimate, and different methods may be used in parallel and the final figure obtained by comparing and adjusting the individual results. The process of estimating is not, therefore, clear-cut and the final result may be an amalgam of different methods on which varying degrees of reliance can be placed. Where, as in many cases, personal experience and judgment cannot be checked either in industry or in the supply Department against suitably analysed data on past projects, then the degree of reliance is likely to be small. Nevertheless, there are clear differences between the various methods and different methods will tend to predominate depending on the stage of the project at which the estimate is made.

143. We can identify at least four methods, which we have called Subjective, Parametric, Comparative, and Synthetic.

144. **Subjective estimating** depends on the recollection and judgment of the estimator and whilst this may sometimes be leavened by personal records, no reliance is placed on systematically recorded and analysed data from past projects. While personal judgment must play some part in the preparation of every estimate, we do not regard this as a sound method of estimating, except possibly when used as a rough check on estimates prepared by other means. We record it here only because of its prominence in a number of the cases studied by the consultants.

145. **Parametric estimating** makes use of formulae which express generalized relationships. These are derived from a statistical analysis of past projects and relate cost or labour or material content to one or more technical or physical characteristics. For example, efforts have been made to establish a relationship between the thrust of a turbo-jet engine and the cost of bench engine manufacture.

146. **Comparative estimating** assesses the cost of a project as a whole or its constituent areas or components at any level, by comparison with formal records on previous projects, making due allowances for differences in type, scale, complexity, and the extent of technical advance. The essence of this method is that it is a process of extrapolation from past experience rather than an attempt to construct an estimate for a particular piece of design work, testing, or manufacture by detailed analysis of the task and its manhour, material, and overhead content.

147. The essential difference between a parametric estimate and a comparative estimate is that the latter is arrived at by reaching a judgment based on expert knowledge of the likely cost relationship between the new design concept and previous projects either in total or by part; the former involves the application of a formula to the selected parameters, judgment residing in the decision that it is appropriate to apply the formula in the particular case. In practice, both parametric and comparative estimates may be made at the same time.

148. **Synthetic estimating** aims to break down the task into its constituent smaller tasks each of which is separately estimated on the best assessment possible at the time, having due regard to past recorded performance, preferably in terms of the effort, material, and facilities required. The total estimate is arrived at by adding these separate estimates together, if necessary with allowances for still unforeseen eventualities. In its extreme form, this method requires a fully detailed design and knowledge of the processes and materials involved, so that a complete analysis of the successive work stages can be made and an estimate constructed using conventional engineering estimating techniques.

149. Nevertheless, synthetic estimates may be made at different depths and the estimates of their constituent parts may themselves vary in degree of definition and precision. In its broadest form a synthetic estimate may consist of a summation of estimates for sub-systems, components, and areas of work arrived at by comparative or parametric methods. Alternatively, estimates may be made using a combination of one or both these methods with traditional engineering estimating techniques. In general, the better defined the item of equipment or activity, the more precise the methods of estimating which can be used and the better in consequence the estimate which is likely to emerge. In the Handbook of Procedures at Appendix M the term 'synthetic estimate' is reserved for an estimate in which the constituent assessments are for activities at a particular level of breakdown, at least a hundred and probably considerably more activities being involved for a major project, each of which may be made by one or other of the above methods, or by the methods in combination. As we have explained in Chapter 5, we believe that detailed synthetic estimates of this type should normally be left to industry.

Stages at which various types of estimate can be made

150. However, whatever the method of estimating employed, as development consists of a series of stages of trial and error, each of which may involve equipment redesign and retest, and as unforeseen difficulties may arise at any stage of development, it is essential to be able to make allowances for these effects since they can be a major cause of under-estimation. This can only be done by informed extrapolation from past experience based on analysed records of previous performance.

151. At the feasibility stage, estimates are made to provide an indication for defence planning purposes of the effort that a given project might be expected to absorb. Only an outline specification of the proposed project is available so that no more than a broad assessment of the effort, timescale, and cost is possible. Design of individual sub-systems cannot normally be defined in any detail so that at this stage comparative and/or parametric estimates based on experience of past projects, even though their limits of error are wide, are likely to be superior to any synthetic estimate built up from very inadequate knowledge of the engineering and programme details.

152. At the project study stage, it should be possible to break the project down into its main constituent parts and sub-systems and to identify tasks and apportion manhours and costs to each but since, at the end of this stage as at present conducted, design of most such parts and sub-systems will not have crystallised in sufficient detail, these estimates will still be largely on a broad comparative or parametric basis, although in better defined areas than at the feasibility stage. As a result the programme and estimates which emerge are not sufficiently well-founded to provide a basis, essential for the satisfactory management of a project, against which subsequent technical and cost progress can be monitored and controlled. Such programmes and estimates do not occur until later when the broad concepts are translated increasingly into detailed designs and decisions are made in areas where there had hitherto been technical uncertainty. Even then, however, uncertainties will remain and there will still have to be a broad allowance for undefined tasks. Nevertheless, the estimate will, on the whole, have been prepared by adding together the estimate for each constituent part of the programme defined in some detail.

153. It is difficult to generalise about the time when this level of synthetic estimate can be made. In the case of a complex weapon system requiring a significant technical advance, it may be some two years from the start of the present form of project study; for simpler less advanced equipments, it may be less. The time taken will vary depending on the nature, size, and complexity of the project and on the technical advance being made. We consider, however, that it should be practicable at the outset of the project study and in consultation with the chosen contractor to forecast how much time and how much work will be necessary to achieve the degree of definition required to prepare a synthetic estimate such as we have described.

154. At a still later stage—the manufacturing stage—when drawings become available and the cutting of metal starts, it is possible to consolidate knowledge about past estimates and to check them against estimates relying more on conventional engineering estimating techniques. The importance of these increases with the ability to define more and more of the

project in terms of 'hardware', but nevertheless even during this stage there are many important elements of the project, such as re-design after test and ground and flight trials, which remain outstanding and for which estimates will depend heavily on knowledge gained from previous projects. Such elements, though decreasing, will remain until all work is completed.

Production estimating and unit production costs

155. We have not attempted in the foregoing to treat production estimates separately. The same sort of estimating techniques will be used as for development, the type depending on the point in the project timescale and the stage of definition reached. Although the difficulties of estimating costs which result from the uncertainty about the full extent of a programme of advanced development, and the resources likely to be required by it, are largely absent in the case of production, an assessment must be made of the effect on the production build (and test) standard of the design changes which will inevitably occur during development. These are difficult to foresee and may have a serious cumulative effect on the ultimate production cost.

156. It is evident from our investigations that the importance of establishing probable unit production costs has not always been recognized. The total cost of production usually runs into many millions of pounds on major projects, even when the ratio between it and the cost of development is low. On smaller projects, production costs may also be considerable, as, for example, in the telecommunications field where total production cost may be twenty times the cost of development before any account is taken of possible exports. It is necessary, therefore, that the combined cost of development and production should be consciously considered from the outset and that the correct balance should be achieved between factors such as size, weight, operating performance, and reliability, on the one hand, and timescale and cost on the other. In some cases an additional period, during or on completion of development, may be justified in order to achieve the best balance and for the application of Value Engineering or other cost reduction techniques. These must, of course, have due regard to the point in time at which the equipment should enter service. The extent of what is possible or justified, and the point in the development timescale at which effort should be applied, will depend on the particular project and the probable production quantities, and it is not possible to be specific.

157. We recommend, therefore, that wherever possible a unit cost aim for production should be given to the contractor at some stage between the writing of the Staff Target and the end of the present type of project study, together with an estimate of the production quantities likely to be required. Nevertheless, care must be exercised over such cost aims. There have been cases where the issue of cost aims has resulted in their being adopted uncritically as estimates of production cost with little regard to the probable work, material, and facilities content of the proposed design. We would emphasize, therefore, the importance of preserving carefully the distinction between the function of the designer and that of the estimator (even if they should be the same person). Only the designer is constrained by the cost aim. The estimator must assess objectively the cost of the equipment as it is defined by the designer; if this estimate exceeds the cost aim, then either the designer must change the design to bring it within the aim or, if this is not possible, the customer must consider whether he wishes to relax the Staff Requirement rather than pay a higher price.

158. Thus ideally the user Department should set, as one of the parameters of its Staff Requirement, a unit production cost aim for the estimated number of equipments required, with the qualification that it wishes to be consulted if it appears that the equipment cannot be obtained for this cost. If this procedure is to be effective, however, the user Department, with the advice of the supply Department, must be able to establish a unit production cost estimate for the number of equipments it is planning to buy which is realistic in relation to the Staff Requirement; otherwise, it will not be possible to make sensible 'trade-offs' between performance and cost should these become necessary. In some cases, however, the establishment of a sufficiently precise and realistic unit cost estimate may be impossible until late in the development of a project, as for example, on a novel and technically advanced equipment. In these circumstances, the user Department may have no alternative but to confine itself to an indication of the total sum likely to be available for production, relying on 'trade-offs' during the study stages and its close association with the project during these stages to reach the best possible compromise between the number of equipments to be supplied and the standards of design and performance to be adopted.

The effects of delays in taking decisions

159. Timing and the need to avoid undue delay between the receipt of project studies and decisions on whether to authorize development are particularly important and we have noted with concern the large number of cases in which delays have occurred. In one of our case studies the time from receipt of project study reports from the firm to the issue of a development contract was over two years. Very little useful work was possible by the firm during this period.

160. In two of the smaller cases we examined, competitive project studies had been obtained. These absorbed scarce resources both in industry and in the Ministry of Aviation, and it is doubtful whether sufficient benefits were obtained to offset this and the delay caused to the start of full development. This danger has now been recognized and current instructions for this technical area lay down that while consideration should always be given to the possibility of competition when selecting a contractor for development work, it must be clear before competition takes place that it will help the Ministry to make the best choice of contractor and that the help so given will be worth the time and effort involved in carrying out the competitive studies and in assessing the results.

161. In one case brought to our attention, the Staff Requirement was withheld from the firm undertaking the work. We consider this wrong and recommend that, subject to the normal safeguards for classified information and, where necessary, to the exclusion of confidential contractual information, contractors should always be given the Staff Target or Staff Requirement on which their work is to be based. This will enable them to get a better appreciation of the user's conception of the equipment required and may lead to the submission of more advantageous proposals during the study stages.

162. The uncertainty implicit in delays between the end of the project study and the decision on full development has been reflected in the contract arrangements during this period. On completion of the project study, it has been customary to place a holding contract on the selected contractor, as was envisaged in the Zuckerman Report, or to extend an existing study contract, pending a decision on full development. These holding contracts or study contract extensions may initially have covered periods of up to about nine months. They have, however, been extended repeatedly, typically by periods of three months at a time, and have not been limited to one period of three months as the report recommended[6]. In one major project we have studied, although full development contracts were never placed because the project was cancelled, work proceeded on holding contracts at two of the main contractors for about two years. Although the initial periods of the contracts were approximately six to nine months each, subsequent extensions were never for longer than three months.

163. The Zuckerman Report[7] considered it essential that during the project study stage, money should be spent at the same rate as if the project had been, in fact, the first stage of a development contract so that if the project ultimately went forward to completion, no time would have been lost. This philosophy has not been adopted, for various reasons, on many holding contracts and in consequence the planned rate of progress has not been maintained. Where the holding contract does not allow the programme to proceed as planned, each extension will of course progressively invalidate the estimates of cost and timescale prepared during the project study.

164. In some cases holding contracts have not been placed until many months after the end of the project study and have had to be made retrospective; in others there have been gaps in contract cover while the contract was being renewed; in others a contract has only been renewed at the last moment before it was due to expire. Rarely has it been possible for work to continue to the planned programme. As a result, uncertainty has been created in the firm as to the Ministry of Aviation's intentions, morale has suffered, and delay to the project has resulted.

Need for improved programming, estimating, and control procedures in industry

165. As the consultants' investigations have revealed, there is considerable unevenness in the application of programming, estimating, and control procedures in industry in the projects we have investigated. At their best, the procedures used approach fairly close to those which are desirable for the efficient management of major development projects, though they have

not been established sufficiently long nor have they built up sufficient background of experience to be fully effective. At their worst, the procedures are rudimentary and carry no conviction that the technical programmes and cost estimates that result from them are realistic and likely to be achieved. Nor is the engineering ability of a firm necessarily a guide to the quality of the procedures employed.

166. When the Ministry of Aviation's current procedures were introduced, it was expected that the discipline of programming in greater depth would lead to fewer omissions in contractors' programmes and to an improvement in their estimates. Some improvements have occurred and the application and development of these procedures over the years have resulted in a fresh look in various sections of industry at estimating and management methods. In order to meet the Ministry's requirements, the more forward looking firms have started to modernise existing organizations or set up new ones. The most important change has been the shift in emphasis from control relying on historic costs, often available only weeks or even months in arrears, towards a system of forward cost budgeting, using the Development Cost Plan as a basis and working through PERT networks or milestone charts.

167. Nevertheless, it is evident that there is still considerable scope for improved project estimating and management methods, and that the need within the supply Department for a more professional approach to project assessment and management that we have already noted in Chapter 5 is matched by a corresponding need in many sections of the defence industry. However, despite the limitations that have been revealed by our investigations, it is evident that a fresh approach to the management of major projects has been developing both in industry and within the Ministry of Aviation over the past five years, and although it has not gone as far, as fast, or as uniformly as it might have done, the benefits of more realistic planning are becoming more widely appreciated and the need for it more generally accepted. We find this encouraging.

Relationships between the Ministry of Aviation and industry

168. As we have already indicated, we have not regarded the question of the Ministry of Aviation's organization as within our terms of reference; nevertheless, we have thought it right to comment on the present organizational arrangements where these impinge on the effective management of projects.

169. The arrangements within the Ministry for the management of projects vary according to the Controllerate and the area concerned. In the Controllerate of Aircraft[8], there are two types of authority: the Design Authority, usually the contractor; and the Approving Authority, normally the appropriate Research and Development Director at the Ministry's Headquarters. On a major aircraft weapon system there may be a number of Design and Approving Authorities. Co-ordination of the project as a whole is the responsibility of the Aircraft Project Director, the airframe constructor being responsible for the integration of the aircraft and its associated equipment into an effective weapon system. The arrangements within the Controllerate have recently been strengthened by the issue, towards the end of 1965, of fresh instructions[9] aimed at providing more unified management on important military aircraft projects.

170. In the Controllerate of Guided Weapons and Electronics[10], there are three main Authorities: the Design Authority, usually the contractor; the Research and Development Authority, usually a Research and Development Establishment; and the Policy Authority, usually the appropriate Research and Development Director at the Ministry's Headquarters. On a major guided weapon or electronics project, there may be a number of Design, Research and Development, and Policy Authorities, each responsible for a particular part of the work. In one of our case studies, fourteen different Research and Development Authorities and four Policy Authorities could be identified though three Establishments were the Research and Development Authority for more than one aspect. Where there is a principal contractor, it is customary for him to act as Co-ordinating Design Authority responsible to a Co-ordinating Research and Development Authority in the Ministry. Co-ordination at Headquarters is carried out by the Project Director for the system under development.

171. Although personal contacts between the Ministry of Aviation and the contractors appeared from the case studies to have been generally satisfactory, several contractors were critical of the Ministry's organization for the management of large development projects.

The main criticisms were that contractors were required to consult and keep informed too many different branches and that projects lacked sufficient unity of direction. On a major system requiring the integration of a number of concurrent and inter-related developments, such consultations took considerable time and effort.

172. Nevertheless, because of the complexity and technically advanced nature of many new projects, multiplicity of contacts is difficult to avoid if the necessary advice and information is to be obtained over a wide range of different specialist activities. Whilst, therefore, we accept that a reduction in the number of contacts is desirable, particularly as our studies have shown that there is a temptation for a contractor to play one authority off against another, we are doubtful whether it is possible to make any drastic reduction in the number of Ministry agencies without adversely affecting the project. However, we recommend that where this is not already done, the Headquarters Project Director should issue a document at the outset which clearly defines the responsibilities of the various Government agencies concerned with the project and the channels of communication between such agencies and the contractor.

REFERENCES

1. The Management and Control of Research and Development, HMSO, 1961, Chapter VII.
2. A feasibility study is defined as 'a study undertaken to identify the scientific and technical problems involved in meeting a Staff Target and to assess whether they can be solved. Normally, it should not involve any experimental work or engineering, but should include approximate indications of the cost and time that would be necessary to complete the project'.
3. A project study is defined as 'a detailed examination of the scientific and technical problems involved in developing a weapon or equipment to meet a Staff Requirement—leading up to a plan of design, development, and testing (quantified in terms of money, manpower, and time) and to an indication of subsequent production costs'.
4. The Management and Control of Research and Development, HMSO, 1961, paragraph 206.
5. See the section on Economic Realism in 'Development Management and Cost Control' by B. D. Blackwell and A. V. N. Reed, Journal of the Royal Aeronautical Society, December, 1965.
6. The Management and Control of Research and Development, HMSO, 1961, paragraph 212.
7. Op. cit. paragraph 201.
8. Handbook of CA Instructions, (Av.P.88), Chapter 301. (See Appendix L).
9. Op. cit. Chapter 111, November, 1965. (See Appendix L).
10. CGWL Notice No. 103. (See Appendix L).

CHAPTER 8

The American Approach to the Initiation and Control of Defence Projects

Introduction

173. Until 1961, defence research and development was treated in the United States as a single broad category for programme formulation and control. Then, as a result of a series of delays to the in-service dates of important projects, massive increases in estimated costs, and failures to achieve the operational performance objective, a thorough re-examination was undertaken of procurement policy.

174. An analysis of twelve U.S. weapon development programmes published in 1962 showed an average cost factor (actual cost divided by original estimate) of 3·2 and an average time factor of 1·36[1], and in 1963, the Director of Defense Research and Engineering listed fifty-seven programmes which had been cancelled during the previous ten years and on which 6·2 billion dollars had been spent[2].

175. The re-appraisal culminated in the issue by Mr. McNamara, the U.S. Secretary of Defense, of a series of related policy directives. This chapter deals with two of the most important of these, the division of research and development into a number of separate categories for the purposes of programme formulation, financial planning, contracting, and control, and the introduction of a funded Contract Definition (formerly Project Definition) phase. This definition phase aims at the establishment, prior to the authorization of the most expensive stage of development, of firm and realistic specifications, identification of high risk areas, selection of the best technical approach, and preparation of realistic time and cost estimates. It is also designed to widen the scope for incentive contracting, a point to which we return in Chapter 10.

Stages of the research and development cycle

176. Responsibility under the Secretary of Defense for the effective direction and control of the overall programme of defence research and development rests with the Director of Defense Research and Engineering. Most of the work is carried out by, or on behalf of, the Departments of the Army, the Navy, and the Air Force, although some is done by other Defense agencies such as the Advanced Research Projects Agency. The research and development cycle is divided for the purposes of this control into five stages: (i) Research, (ii) Exploratory Development, (iii) Advanced Development, (iv) Engineering Development, and (v) Operational Systems Development.

177. Research includes all basic research and, in addition, that applied research directed towards the expansion of knowledge in various scientific areas. It does not include efforts to prove the feasibility of solutions to problems of immediate military importance.

178. Exploratory Development includes all effort directed towards the solution of specific military problems, short of major development projects. This type of effort may vary from fairly fundamental applied research to quite sophisticated breadboard hardware, study, programming, and planning efforts. It thus includes studies, investigations, and minor development effort. The dominant characteristic of Exploratory Development is that the work is pointed towards specific military problem areas, with a view to developing and evaluating the technical feasibility of proposed solutions and determining their parameters.

179. The outcome of effort on Research and Exploratory Development may be very different from the original goals and it is necessary to have technical control over the contractors' work and to be able to pursue alternative approaches. Cost estimating for such work is difficult and programme control is exercised by technical monitoring and supervision of the level of effort employed.

180. Advanced Development includes all projects that have moved into the development of hardware for experimental test, but are not yet being designed and engineered for eventual

Service use. Projects in this category are usually for the development of experimental components or sub-systems which are expected to have a future military application.

181. Engineering Development includes those programmes in which the item is being engineered for Service use, but which have not yet been approved for production or operation. It is concerned with the engineering of components and sub-systems into operationally suitable items. Engineering Development projects are initiated only when there is an approved military need.

182. Operational Systems Development is similar to Engineering Development but is limited to projects that have been approved for production and Service deployment.

183. Programme control on Advanced Development, Engineering Development, and Operational Systems Development is by project.

184. The President's Budget for the American fiscal year 1966 expressed in terms of the five categories was:

Research	6·5%
Exploratory Development	21%
Advanced Development	13·5%
	41%
Engineering Development	24%
Operational Systems Development	35%
	59%

Milestones in the life of a typical weapon system

185. The main milestones in the life of a typical weapon system are:

1. Development of basic technology
   (Research and Exploratory Development)
2. Formulation of an Operational Concept
3. Generation of 'building blocks'
4. Feasibility test of experimental hardware
   (Advanced Development)
5. Establishment of a Specific Operational Requirement and incorporation of the new project into the approved forward programme
6. System development
   (Contract Definition, Engineering and Operational Systems Development)
7. System acquisition
   (Production)
8. System operation.

The most important stage in the life of any project is the transition from Advanced Development to Engineering or Operational Systems Development.

Concept Formulation and Contract Definition

186. The activities preceding a decision to make this transition are known as Concept Formulation. They cover the comprehensive studies, the manufacture of experimental hardware,

and the testing carried out under Exploratory and Advanced Development. Conditional approval to proceed with Engineering Development is given only if Concept Formulation can be shown to have satisfied the following conditions:

(a) primarily engineering rather than experimental effort is required;

(b) 'building block' components and technology needed are sufficiently in hand;

(c) a thorough analysis has been made of the various permutations of performance, cost, time, etc.;

(d) the best technical approach has been selected;

(e) the mission and performance envelopes are defined and are optimized for technical feasibility and cost-effectiveness;

(f) the cost-effectiveness of the proposed item compares favourably with the cost-effectiveness of other competing items in the defence field; and

(g) cost and time estimates are credible and acceptable.

187. The intention of the first two conditions is that the development should be primarily a systems engineering effort rather than one of component development. Component and technology development are expected to take place in the Exploratory or Advanced Development cateogry. Whilst it is not intended that Engineering Development will be limited to an assembly of off-the-shelf components, the technology required to meet a system specification should not exceed the performance that has been demonstrated in experimental or laboratory form, that is, the known state of the art. Together, these pre-requisites force a substantial degree of preliminary development, planning, and definition of the fundamentals before the project proceeds to Contract Definition. The request for approval for Engineering Development is accompanied by a Technical Development Plan outlining the history of the studies and development to date and a plan for the conduct of Contract Definition. The request is submitted by the sponsoring Military Department to the Directorate of Research and Engineering who forward it to the Secretary of Defense after all the necessary prior consultations have been completed. If he approves the request, the project is then incorporated in the forward defence programme.

188. When conditional approval for Engineering Development has been given following Concept Formulation, Contract Definition is undertaken to see whether the conditional approval should be ratified. The objectives of Contract Definition are to:

(a) provide a basis for a firm fixed price or fully structured incentive contract;

(b) establish firm and realistic specifications;

(c) define inter-faces and responsibilities precisely;

(d) identify high risk areas;

(e) validate technical approaches;

(f) establish firm and realistic time and cost estimates for full development (including production engineering, facilities, construction, and production hardware that will be funded during development)—this means that each contractor has to analyse the development in terms of the activities and events required, prepare a work breakdown structure, and draw up PERT/Time and PERT/Cost estimates; and

(g) establish time and cost estimates for planning purposes for the total project (including production, operation, and maintenance).

189. Concept Formulation and Contract Definition are mandatory for all projects requiring cumulative research and development funding in excess of \$25 million or estimated to require production funds in excess of \$100 million. Such projects account for some 85–90% of the total expenditure. Smaller projects may also be required to go through one or both of these phases.

190. Contract Definition is generally undertaken by two or more competing contractors and an elaborate procedure has been evolved for conducting it—

Phase 1A. A Request for Proposals (RFP) is issued to which contractors respond with firm proposals for Contract Definition and planning proposals for Phase II. These are evaluated, contractors are selected for Contract Definition, and Contract Definition contracts are negotiated and awarded on fixed price terms.

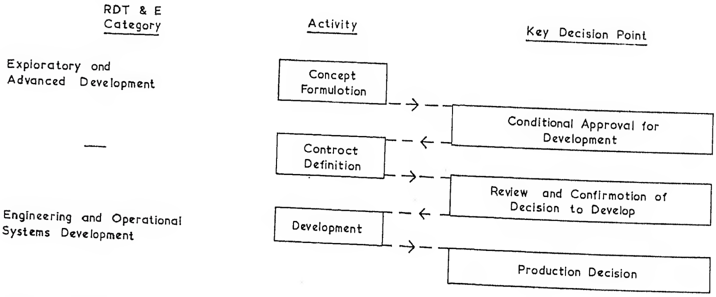
Phase 1B. The contractors define the proposed full scale development, including technical, performance, design, cost, time, and management aspects, relying heavily on trade-off studies (aimed at optimizing the balance between operational effectiveness, time, and cost) and PERT/Cost, and submit their reports on Contract Definition and firm proposals for Phase II.

Phase 1C. Negotiations and technical discussions are started with all competing contractors; the proposals are evaluated, selection of the contractor is made for Phase II, and the contract is negotiated.

Phase II. A definitive contract is awarded for full scale development, normally on an incentive basis.

191. If the objectives of Contract Definition have not been realised during Phase I, a decision may be made either to undertake further Exploratory or Advanced Development of key components, or to abandon the project. The aim is to complete Contract Definition within nine months, but this period has been exceeded in many cases and is generally held to be inadequate. In particular it was found that considerable time was necessary to complete Phase 1C. An analysis by the Department of Defense of the first six projects to undergo Contract Definition shows that three were in Phase 1C for nearly a year and two others for twenty to forty weeks. In an effort to expedite the completion of Phase 1C, a goal of eighteen weeks has now been set for it. The time required for Concept Formulation is of course additional to that spent on Contract Definition. As an example, Contract Definition for the C.5A aircraft was completed in nine months, but Concept Formulation occupied just over a year, and this was a project regarded as being within the state of the art.

192. The diagram below shows the relationship between the Concept Formulation and Contract Definition processes and the various research, development, test, and evaluation (RDT & E) categories.


RDT & E Category
Activity
Key Decision Point
Exploratory and Advanced Development
Concept Formulation
Conditional Approval for Development
Contract Definition
Review and Confirmation of Decision to Develop
Engineering and Operational Systems Development
Development
Production Decision

193. In the light of experience on earlier projects where the 'grey' areas had not been adequately probed before Engineering Development was undertaken, increased effort and expenditure is now being put into Concept Formulation (including Exploratory and Advanced Development) and Contract Definition. The tendency is to switch to these stages more of the work previously carried out under Engineering Development, and a decision to proceed with the latter is not given until it can be clearly demonstrated that the objectives of Contract Definition have been met. The amount of money being spent in these initial stages is indicated by the following:

1964/65 Budget			*$ Million*	
	Research	*Exploratory Development*	*Advanced Development*	*Engineering and Operational Systems Development*
United States Air Force	93	318	310	1846
%	4	12	12	72
All Departments of Defense	354	1122	572	3127
%	7	22	11	60

Appraisal of U.S. procedures

194. The main criticisms that have been made of these procedures in the United States are that:

(a) a very large staff effort is required and elaborations are constantly being introduced which increase the burden. Some idea of the numbers involved is given by the fact that the Air Force deployed over four hundred staff for five months to read and evaluate the five competitive proposals that were received on the C.5A airframe and engine and nearly one thousand on another project for a much longer period;

(b) fixed price contracts are normally awarded for Contract Definition but the competitors incur costs much in excess of those covered by their contracts in their efforts to secure the contract for Engineering Development (for example, in one case, three airframe competitors spent $15–20 million each in addition to $6 million paid to each firm by the Air Force). This additional expenditure, which is not reimbursed by the Government, may more than offset the profit made by the selected contractor through cost savings under the incentive contract, and have undesirable repercussions on the execution of the contract; and

(c) contracts for Engineering and Operational Systems Development produce obsolete equipment because of the attempt to plan everything in advance and the need to discourage changes which would upset incentive arrangements but which might otherwise be desirable on technical merit.

195. The first two of these criticisms are currently of considerable concern at senior level in the U.S. Department of Defense and the intention is to reduce costs in future by limiting the Contract Definition competition on a project to two contractors. A very substantial staff effort is probably inescapable, however, since literally tons of documentation are produced by contractors because of the requirement that, where incentive contracting is to be adopted, the whole subject matter, (specification, test schedules, technical development plans, etc.), must be so comprehensively defined that the Department can relinquish technical control (as distinct from monitoring) and expect to get equipment satisfactory for Service use. An interesting feature in this connection is that contractors' proposals have to identify the key personnel responsible for managing the project and these cannot be changed without the Department's approval. This was done to defeat the practice of withdrawing high calibre staff from the project subsequent to the winning of the contract. As regards the third criticism, a fundamental choice has been made in favour of getting a specified system on time at an established cost as against adapting and upgrading the requirement as the project proceeds, with consequent delay and loss of cost control. This may be an easier choice to make in American conditions where there is frequently a sequence of projects for a particular role, each involving only a limited technical advance and following on each other at relatively short intervals.

196. The extent to which the areas of high risk and uncertainty have been eliminated by the time the Engineering Development contract is placed varies between projects, and for some of the earlier ones no great claims can be made on this score. It is accepted that no amount of prior study or practical work can eliminate the areas of risk completely, but it is believed that careful definition of the work to be done exposes them to the point where it can be decided whether they are acceptable to contractors and Government in the context of incentive contracting.

Major differences between U.S. and U.K. approach to development

197. There seem to be two major differences between the U.S. and U.K. approaches to development:

(i) in the United States, it is the aim not to authorize full development until the technology involved in the project has been demonstrated during the Exploratory and Advanced Development stages, whereas in the United Kingdom the type of work necessary to achieve this is often an integral part of the work carried out after the commitment to full development has been entered into. This difference is due in part to the relative shortage of funds for research and development in the United Kingdom which has often meant that, even though the work might be useful in meeting a possible Staff Requirement, it could not be authorized until the Requirement was approved; and

(ii) the technical requirement and work programmes are now precisely defined in the United States before Engineering Development is approved and before incentive contracting is attempted; in the United Kingdom, full development is frequently authorised before the specifications are sufficiently well defined and while the work programme is still subject to major uncertainties. As a result clarification only emerges as work proceeds.

198. A common reaction within the United Kingdom to the American 'building block' approach to development, and their determination not to embark on Engineering Development until a full evaluation has been made and a detailed specification prepared, is that it would prolong development to an unacceptable extent. It is the firm U.S. conviction, however, that in the long run their new methods will result in a substantial decrease in the number of changes made during full development, significant savings in total cost and time, and the cancellation of fewer projects in full-scale development, since they aim to avoid situations, which used frequently to occur, where the project was held up, redirected, or even abandoned, because of unforeseen technical problems. However, since Contract Definition has only been in existence in its present form since February, 1964, it is too early to say whether this expectation will be fulfilled.

REFERENCES

1. The Weapons Acquisition Process—An Economic Analysis, Peck and Scherer, Harvard Business School, 1962. Table 2.1 on page 22.
2. Testimony before the Congressional Sub-Committee on Military Appropriations.

CHAPTER 9

The French Approach to the Initiation and Control of Defence Projects

Initiation of projects

199. As in the United Kingdom a project begins with the preparation of a Requirement by the operational staff of the Ministry of Defence. After this has been given preliminary policy approval, exploratory studies (études d'avant projets) are carried out in industry in rather greater depth than the U.K. feasibility study. The amount of work involved is much less, however, than in the present type of U.K. project study and the nearest French equivalent to this, the 'marché de definition', is seldom undertaken. These exploratory studies are often carried out by a number of contractors in competition and normally no payment is made for them. The main outputs are a first estimate of cost, which is used to check that the project can be funded from the military budget section of the current five year plan, and a technical specification. It appears that this specification is less precise than the type now prepared here as part of the project study or during the first phase of development.

200. The French Five-Year Plan is not a plan for the next five years, but a plan for a five-year period for example, 1966 to 1970. It thus differs from the U.K. Defence Costings which move forward every year so that the next five years is always covered in detail and the second five years in outline. The total commitments that the Executive proposes to incur on a particular service or project are shown in the five-year programme, or Loi-Programme, submitted to the French Parliament. The approval of the Loi-Programme by the French Parliament although it clearly defines the forecast estimates of expenditure and their division year by year, does not of itself give authority to spend money. It has no counterpart in U.K. Parliamentary procedure. Authority for making payments is obtained annually through the Budget, which does two things. It contains the expenditure estimates for the year ahead, which fixes the amount that can be committed on a project, and it also contains estimates of payments which may include any payment grants left over from earlier years. The five-year plan and annual estimates are prepared within the context of rigorous economic planning and Supplementary Estimates, although not unknown, are extremely difficult to obtain under the French Parliamentary System. The French use this difficulty as part of their machinery of control.

Contract arrangements

201. On aircraft projects, the French usually first place a contract for the design and construction of one or more prototypes. This contract is normally at a fixed price, sometimes with a clause allowing the price to be revised in the light of changes in certain official price indices, for example, those for wages, social security charges, and raw materials. It also includes a financial penalty for delay if the specified date for delivery is not achieved. Particular emphasis is placed on attaining the earliest possible first flight date, and the general philosophy at this stage is to give cost and timescale rather greater weight than operational effectiveness. The subsequent work of re-design, aircraft modification, and development flying, which is needed to bring the aircraft up to the required standard, is carried out on cost reimbursement type contracts although rigid limits may be set on expenditure and commitments year by year.

202. The French practice of placing fixed price contracts at a very early stage for the manufacture of prototypes makes them reluctant to adopt the U.K. method of working to a Development Cost Plan, although they have accepted this on the Concord and Jaguar aircraft projects. They believe that an early detailed search for costs tends to inflate them and that the best way to carry out development economically and to a timescale is to place contracts at fixed prices from the earliest possible moment. While we agree that fixed price contracts give contractors a powerful incentive to efficiency, they are considered practicable in the United Kingdom only if they are related to a definitive specification. The French do not accept that such detail is required at the outset provided the contract lays down a procedure for agreeing the detail and assigning liability and for establishing the acceptability of the final equipment.

203. The French pay great attention to estimates of unit production cost and, as in the United Kingdom, production contracts are normally placed at fixed prices. Moreover, they expect their contractors to quote for production well before development is complete. The quotation given in France relates only to an early flight standard, but the French claim that the addition that has to be allowed for later modifications does not normally exceed 10%. This low figure may be connected with the existence of formal controls over design changes from an early stage of development. In balancing cost against performance, they seem to give considerable weight to cost and to timescale as an aspect of cost.

204. It is the aim to agree all prices with the contractor, but they can in the last resort be determined by the Departmental Minister. Apparently this power is very seldom used.

205. The French Government have a statutory right to obtain information on the actual costs of all contracts, including fixed price contracts. This information is used for preparing preliminary estimates for policy consideration and to assist in pricing future contracts for similar work at the same or other contractors, including production and spares contracts for equipments under development. It cannot be used for the re-negotiation of contract prices that have already been fixed.

206. Every French firm engaged on contracts for the Government must follow a standard accounting system. As a result information is available in the same form at every contractor and all items are dealt with in a uniform manner. Government contracts lay down the classes of labour which are regarded as productive and which must be charged direct. This simplifies price-fixing and is different from the position in this country where the details of the cost allocation system vary from firm to firm and are subject to negotiation.

Arrangements for project administration

207. In France, the operational requirements staff and the supply staff are members of the same Department, which also contains an out-posted member of the Ministry of Finance. In addition, the French have a more integrated system of administration in that their executive branches, which are almost entirely staffed by a special corps of technicians with administrative training who have been though the École Polytechnique, not only carry out all the management functions of the Ministry of Aviation's technical branches, but also much of the policy work of its finance branches and some of the work of its contracts branches. There is also greater continuity of staff. This concentration of authority, besides making for greater economy, allows decisions to be taken more quickly and gives greater force to the system. There is no counterpart in France to the lengthy inter-branch and inter-Departmental discussions which take place here; nor do the French have the same interlocking committee structure. On the other hand the French procedures for the issue and amendment of contracts are more complicated and time-consuming than those of the Ministry of Aviation and there is less use in French industry of advanced programming and cost control techniques. There are also indications that some recent changes in the French administrative system may be tending to lose them some of their previous advantages of centralized control.

208. Because a larger proportion of development work is undertaken at fixed prices, there is less oversight of work in industry in France than in the United Kingdom. The French have only small staffs and leave a large degree of freedom to industry and generally try to follow the principle of non-intervention. This may be partly due to the fact that three of the largest firms in the French aircraft industry (Sud-Aviation, Nord-Aviation, and SNECMA) are nationalized. However, very close relations exist between the French Ministry of Defence and the nationalized firms of the aircraft industry and they are best thought of as two complementary parts of a single public service system. The leading figures on both sides tend to be products of the same background and may have been former colleagues either at the École Polytechnique or in the civil service.

Conclusion

209. There are a number of features in the French system from which we can learn, notably the more compact inter-Departmental organization and the greater authority and independence of their administration, the more rigid control of design changes and the power to post-cost contracts. The steps which have recently been taken here to increase the centralization of

project management and the efforts being made to obtain post-costing rights go some way in this direction. On the other hand, there is a fundamental difference in practice between the two countries in the matter of development cost estimating. The French, as stated in paragraph 202, do not believe in the preparation of Development Cost Plans for full development in the same detail as we, but rather proceed by empirical steps from an initial prototype with the aid, so far as possible, of fixed price contracts within an overall outline budgetary plan. We have considered whether it would be possible to adopt a 'one step at a time' approach during the main development phase with the greater flexibility that this would seem to allow. We concluded, however, that this would be difficult to reconcile with the present United Kingdom procedures for authorizing development work. Our system of looking ahead to completion, allied to the elaborate machinery associated with this (for example, the Ministry of Defence Operational Requirements and Weapons Development Committees and the ten-year defence costings) is inimical to a fragmented approach and it is no longer possible to return to this for the generality of large projects without a radical revision of the present long-term planning arrangements. Moreover, we are convinced of the need for detailed project definition to be reached as early as possible and before the main development contracts are placed, and we believe that the French are also moving in this direction.

CHAPTER 10

The Scope for Incentives in Development Contracts

Introduction

210. It is generally accepted that the cost plus percentage profit contract not only fails to provide an incentive to economy, but may actually encourage uneconomic working and performance. It has, therefore, long been the Ministry of Aviation's policy to try to negotiate wherever possible a form of contract which provides the contractor with a financial incentive to keep his costs to the minimum compatible with the satisfactory performance of the work. The successful use of incentives in development contracts (particularly those placed at a fixed or a maximum price) would reduce considerably the need for the supply Department to monitor the contractor's progress during development, and could do much to reduce the present difficulties experienced by Government in forward budgeting for defence research and development expenditure. The negotiation of incentives is, however, dependent firstly on the establishment of firm and realistic specifications, and secondly on the ability to make realistic estimates of cost and time based on those specifications. Thus, the prospects of implementing a policy of incentive contracting are bound up with those of achieving sound cost estimates. Unfortunately development work, particularly advanced development work, necessarily involves a degree of uncertainty which militates against this. We therefore thought it right to review recent experience with incentives in development contracts and to consider whether some further advance could be made.

211. We first sought to establish the pattern of incentive contracting in the development field covered by the Ministry of Aviation since Sir William Strath issued the instructions on the financial control of research and development reproduced at Appendices B and C. We were greatly helped in this by the Report of a Study Group set up by Mr. E. W. G. Haynes, the Under-Secretary in charge of the Contracts Division, in December, 1964[1]. We next examined recent developments in American policy and practice and we include at paragraphs 220 to 240 below extracts from the report made by Mr. Haynes, following his visit to the United States for this purpose in October, 1965[2]. Finally, and against this background, we reviewed the possible scope for an increase in incentive contracting in this country and the extent to which it might be used to stimulate improved development cost estimating and to assist in controlling development costs.

Types of incentive

212. Cost incentives may be incorporated in a contract by various pricing arrangements, for example, fixed prices, maximum prices, target prices with a profit sharing formula, or reimbursement of costs with a fixed fee for profit negotiated in advance. In all these the expectation is that the more economically and generally the more expeditiously the contractor completes the work, the higher the rate of profit he earns. The type of arrangement used must be in keeping with the technical (and hence financial) risks involved; for instance, a fixed price would not be appropriate for a high risk, large value contract. Only fixed and maximum prices place a limit on the total payments by the supply Department and then only if the contractor is financially strong enough to bear any resulting loss. Target price and fixed fee contracts provide no such limit and in a situation in which a contractor can recover his costs there is a danger, unless there is a reasonable prospect of sufficient new work, of existing work being drawn out even though this may reduce or even eliminate his profit.

213. Incentive arrangements can also be introduced for other features (for example, performance (that is quality), delivery, or Value Engineering) which also have a bearing on the costs of carrying out the work.

U.K. experience

214. The Ministry of Aviation Contracts Division Study Group obtained information about the research and development contracts placed by the Ministry during the years 1960–64 inclusive, and the incentives which had been negotiated. This showed that at the time of the survey incentive arrangements covered 42% of the total value of research and development

contracts placed during the period. This figure, however, covered a range of contract types in which the strength of the incentive varied widely, and included one large contract in which the main incentive was a relatively mild one of a variable profit with upper and lower limits. If this contract were to be treated as a non-incentive contract, the figure of 42% quoted above would fall to 30% and this probably gives a more accurate representation of the success that has been achieved in obtaining incentive arrangements in recent years.

215. Incentive arrangements in the major cases (that is, contracts valued at more than £500 000 for aircraft, engines, and guided weapons, and more than £100 000 for aircraft equipment and electronic projects) have nearly all been in the airframe, engine and accessories field, where the pattern of development has been more established and new projects were generally only a further step or two along the road of new techniques. In the guided weapons and electronics field, where research and development tends to be more on the fringe of the unknown and major advances in technology may be expected in any new programme, only a small percentage have included some form of incentive; inability to define the requirement with sufficient precision, or uncertainty about the work programme needed to meet the requirement, precluded the negotiation of incentives for the remainder. In the case of contracts below the limits mentioned above, however, the proportion with an incentive was much the same in both fields (between 20 and 25%).

216. The Contracts Division Study Group found it hard to assess the benefits from these incentive contracts. In theory, in order to negotiate them the Ministry of Aviation had to define its requirements carefully and in detail, and the contractor had to prepare a well considered programme and cost estimate. Since the incentive schemes in effect related the contractor's rate of profit (or loss) to the degree of efficiency achieved, they also could be expected to have induced him to exercise effective technical and financial control over the work. However, in the absence of readily available information on out-turn of costs on fixed price work and on performance in meeting completion dates, the Study Group did not find it possible to generalize on the extent to which the potential advantages had been realised in practice, although there was evidence that a number of contractors had found it difficult to keep their costs within the fixed or maximum prices they had accepted.

217. We therefore commissioned a special review of eleven selected contracts covering a number of fields of development activity and a variety of incentive arrangements. This review revealed that, provided certain conditions were fulfilled, the existence of a fixed or maximum price or target cost contract was considered by the Ministry branches concerned to have stimulated the contractor into exercising close control over both time and cost with the result that the work had been satisfactorily completed either on time or nearer the target date than would probably have been achieved on a cost reimbursement contract. Where these conditions were not fulfilled (for example, when the specification was subject to substantial amendment), the existence of an incentive contract had sometimes turned out to be more of an obstacle than an aid to the efficient implementation of the Ministry's requirements.

218. The conditions which this review, and other Ministry of Aviation experience, suggests are necessary before an incentive contract can be fully effective may be summarized as follows:

(a) the supply Department must be able to issue to the contractor a detailed technical specification of its requirements, including where necessary a schedule of the tests that will have to be carried out to demonstrate that the developed equipment meets the technical specification;

(b) the supply Department does not expect to have to propose any radical alterations to the specification during the course of work and there must be a well-defined and quick procedure for dealing with minor amendments;

(c) the supply Department must be content for full technical control to be exercised by the contractor;

(d) there must be little or no overlap between work on the incentive contract and similar work priced on a substantially different basis (for example, cost plus percentage profit) which can give rise to cross-bookings of cost. (This factor may not be so important where close controls can be maintained to ensure correct allocations of cost.);

(e) the contractor must not be unduly dependent for the achievement of his planned programme on the issue by particular dates of a number of embodiment loan items being developed by other firms under direct supply Department contracts;

(f) successful development must not be dependent on the resolution during the programme of major technical uncertainties, that is, the work should generally be within the known state of the art;

(g) the contractor must be able to predict the total work-load on his facilities at least for the expected period of the contract; and

(h) the contractor must be able to prepare, and the supply Department must be able to evaluate, a realistic estimate of the cost.

The Contracts Division mission to the United States

219. It seemed to us at first sight that it was only in the exceptional case that all these conditions would be fulfilled, but in view of the information that had been obtained about the increased use of incentives in development contracts placed by the American defence Departments, we welcomed the decision to send a Ministry of Aviation team to the United States in October, 1965, to study incentive contracting for defence procurement. This we felt would enable us to gain a detailed understanding of American policies on incentive contracting for defence supplies, to study the implementation of these policies over a range of projects, and to attempt to judge their effectiveness and suitability for use in Ministry of Aviation purchasing. The following paragraphs (numbers 220 to 240 inclusive) are taken, with slight editorial amendments, from the team's subsequent report[2].

Evolution of American incentive arrangements

220. Until 1961, the U.S. defence Departments made widespread and increasing use of cost plus fixed fee contracts (CPFF), particularly for research and development work. Under this contract type the contractor is reimbursed for whatever allowable costs he incurs and is paid a fee for profit which is fixed when the contract is let. The cost plus fixed fee contract is regarded in this country as a mild form of incentive arrangement, since the higher cost the smaller the percentage profit. But to the Americans, who are debarred by statute from placing straight cost plus percentage profit contracts, it is the basic type of non-risk contract. Great difficulty was experienced in getting reliable estimates and controlling costs, particularly for development work, and it was considered that this was due largely to lack of planning, unsystematic methods of trying to define requirements, and to the fact that the cost plus fixed fee arrangement gave contractors little stake in the outcome and accordingly little incentive to control costs.

221. New policies were evolved during 1961–1963 which have as their main aims:

(a) an orderly progression of a project through the various stages of research, development, and production, with great emphasis at the development stage on defining the requirement, high-lighting and resolving major technical uncertainties before large commitments are entered into, and producing realistic time and cost estimates; and

(b) the use of financial incentives in contracts for Engineering and Operational Systems Development (see Chapter 8) and for production, in order to encourage contractors to reduce costs, improve quality, and achieve completion or delivery targets.

222. The chief advantages expected from the introduction of these new policies are, briefly:

(a) avoidance of the substantial nugatory development on projects cancelled because of technical difficulties not foreseen at the outset or escalating costs;

(b) earlier delivery, better performance, and reduced costs on individual contracts through operation of the incentive policy; and

(c) significant savings in total systems cost (including facilities, personnel training, etc.) by obtaining optimum balance between total cost, time, and operational effectiveness (including performance, reliability, and maintainability); account is taken of these factors from the inception of the project, and through the design stages.

223. The basic types of incentive contracts now employed by the U.S. defence Departments are:

(a) *Cost Plus Incentive Fee* (*CPIF*). This comprises a target cost, target profit, and a formula under which the overruns on target cost are shared between Government and contractor on a basis defined in the contract, thus reducing or increasing the contractor's profit. There is no ceiling price and thus all allowable costs are paid by the Government. Normally there is also a stated maximum and minimum profit fee. This contract type is used where the uncertainties in contract performance are sufficient to preclude a fixed or maximum price, but not so great as to justify the use of the Cost Plus Fixed Fee (CPFF) contract.

(b) *Fixed Price Incentive* (*FPI*). This has a target cost, target profit, a sharing arrangement, and a price ceiling. The latter, together with the fact that no maximum or minimum profit is prescribed, distinguishes it from the CPIF type.

(c) *Firm Fixed Price* (*FFP*). As in this country, this is the preferred type, providing maximum incentive to the contractor.

224. The choice of contract type is mainly determined by the degree of confidence in the cost estimate. The characteristics of the various types in this respect are:

	Probable magnitude of	
	Underrun	*Overrun*
Cost Plus Incentive Fee	10% or more	20% or more
Fixed Price Incentive	5% to 10%	10% to 20%
Firm Fixed Price	5% or less	up to 10%

The degree of confidence is further reflected in the first two types by the sharing formula, for example, in a recent sample the contractor's share of overruns and underruns on cost plus incentive fee contracts was usually 15% whereas on fixed price incentive contracts it ranged from 30 to 50%. The aim is to make the incentive arrangement cover the entire range of foreseeable variations from the cost estimate so as to maintain the incentive during the whole of contract performance. Emphasis is also placed on providing the widest spread between maximum and minimum profit fees (for example, on a cost plus incentive fee contract for research and development, from zero for poor performance to 15% for outstanding performance), so as to make the contractor's share of overruns and underruns on target cost as high as possible over any given range of cost outcome.

225. The following table shows the usage of the various contract types by the United States Air Force for research and development work in 1962 and 1964:

	New contract obligations—% by value	
	1962	*1964*
Cost Plus Fixed Fee	80	29
Cost Plus Incentive Fee	13	29
Fixed Price Incentive	1	18
Firm Fixed Price	5	19
Other	1	5

226. The main feature in the last few years has thus been the great reduction in cost plus fixed fee contracts, but it is necessary to look at the details of the individual contracts to assess whether these are likely to be more effective in controlling costs and inducing efficiency. Many of the early incentive contracts were in fact little different from cost plus fixed fee type, for example, they did not include price ceilings, and incorporated weak share lines on overruns and underruns on target cost (for instance 94% to the Government as against 6% to the contractor). The unsatisfactory nature of these early contracts has been demonstrated by continuing experience of large overruns on cost plus incentive fee contracts. As experience and data accumulate, techniques are being further developed, both for arriving at a satisfactory base for incentives, and in the incentive arrangements themselves, and recently more ambitious schemes have been attempted.

227. Despite the efforts to achieve better definition and closer cost estimating prior to Engineering Development, some U.S. agencies believe that there is little prospect of obtaining stronger cost incentives than those provided by cost plus incentive fee arrangements for the development of advanced projects which, although they appear to be within the state of the art, can give rise to serious problems not foreseen at the outset. A technique recently adopted by the U.S. Air Force which may offer an effective way of dealing with this situation is the flexible share arrangement whereby the contractor starting off with a relatively weak share ratio can elect, for the balance of the contract, to increase his share of underruns and overruns on the target cost at specified intervals and within prescribed limits during the currency of the contract. The idea is to encourage the contractor to accept more risk in return for greater profit as he becomes more confident of the outcome, and thus to maintain the incentive for cost reduction throughout the programme. The Department of Defense is pressing the supply Departments to use fixed price contracts to a greater extent and, certainly in the less advanced kind of work, there has been considerable response. Recent projects covered in whole or in part by fixed price incentive contracts include the F.111, A7A, and C5A aircraft.

228. Some of the troubles experienced in the United States with cost increases on development projects stem from the fact that the Government's capability for cost estimating or validating contractors' estimates in this field has not been very high, and undue reliance has been placed on contractors' estimates (which were sometimes purposely pitched too low in order to get the work). Although a considerable amount of data on past projects has been available throughout the Departments, it has not been systematically analysed to develop trends and yardsticks for estimating purposes. This is now being remedied by recruitment and training of statisticians, analysts, and engineers to collate and interpret the data. A good deal of work has already been done on aircraft development costs in connection with the C.5 and F.111 aircraft and on propulsion systems, and analysis of missile data is now in hand.

Performance and delivery incentives

229. Performance and delivery incentives have also been used increasingly in the United States in recent years in addition to cost incentives, the theory being that a positive emphasis, spurring the contractor through the profit motive, is more effective and administratively simpler than reliance on legal remedies such as termination for default and provisions for liquidated damages. In 1964/65, nearly half the contracts placed on an incentive basis were of the multiple incentive type. The application of the incentive varies according to the stage of the project. In the development phase the main emphasis is usually on performance; cost and delivery are stressed in production contracts.

230. The method of 'structuring' the multiple incentive is first to determine the total target profit fee (representing normal profit for an acceptable job) and then to divide this in the desired proportions between the cost, performance and delivery incentives; the target fee for each of these aspects is then varied up or down for success or failure. A typical example is the Cost Plus Incentive Fee contract for a major missile system, where the target fee was fixed at $19·9 million, representing a normal profit rate of 7%. The division of this target fee between the various incentives, and the rate of profit added or deducted according to achievement, was as follows:

Incentive feature	*Target fee* $ million	*Target profit rate* %	Reward *Additional profit rate* %	Penalty *Reduction in profit rate* %
Cost: scaled sharing arrangement within range of ± 30% of target cost	8·7	7	1·75	1·75
Performance: system performance	9·1		3·0	2·25
Bonus reward for successful first model flight	—		0·5	—
Delivery: PERT milestones and selected events	2·1		—	0·75
	19·9	7	5·25	4·75

Maximum profit rate *12·25%*
Minimum profit rate *2·25%*

Thus, although all allowable costs would be paid by the Government, success in meeting the cost, performance, and delivery requirements would be rewarded with a profit rate ranging from 7 % to a maximum of 12·25 % of the target cost, according to the degree of achievement: the penalty for not meeting these requirements would be a reduced profit rate, ranging from below 7 % to a minimum of 2·25 % according to the degree of failure.

231. The U.S. Department of Defense consider performance incentives to be of great value in development contracts, particularly those let on cost plus incentive fee terms, which, because they have no price ceiling, are in effect 'best efforts' arrangements without performance guarantees. The most usual scheme is to attach a reward and penalty formula to particular features such as weight, speed, range, take-off and landing distance, in circumstances where some flexibility in the level of performance is permissible and there is real value in obtaining the maximum possible performance under the proposed design approach. Minimum performance levels are set for the various parameters and these are pitched so that there is every possible assurance that they will be achieved (feasibility will have been confirmed during the Contract Definition phase). Upper performance limits are then fixed which are attainable within the confines of the contractor's technical proposal and do not require any significant technological break-throughs or alterations in the design approach. Within these two limits a target performance is chosen to which the target fee is allotted and variations to the fee reward good and penalise mediocre performance. Where a fixed price incentive contract is used the minimum performance levels must be achieved at no extra cost beyond the ceiling price. On a cost plus incentive fee contract there is of course no commitment by the contractor to achieve the minimum performance within a specified cost.

232. Delivery incentives are the least used of the incentive features and when applied are always given less emphasis than the cost or performance aspects. Whilst the same type of arrangement as described above for performance incentives may be used, (that is, a target with variable fee on either side of it), the more usual scheme now in production contracts (where delivery incentives are most frequently used) is to pay the target fee for delivery by the required date and to reduce it for late delivery. There is no additional reward for early delivery. A typical arrangement in long duration development contracts is to have a combination of incentives for achievement of interim milestones and final delivery, particularly where the former are critical in relation to work being done on the project by other contractors.

233. A number of problems have been experienced by U.S. supply Departments in using performance and delivery incentives, the main ones being that:

(a) the satisfactory operation of performance incentives is vitally dependent on definition of parameters and methods of test. These aspects are very complex (for example, aircraft speed can only be defined by specifying test altitudes, instrumentation, loading, atmospheric conditions, etc.) and it is often not possible to foresee, when the contract is placed, circumstances perhaps several years ahead which will affect the outcome. Performance incentives have sometimes failed to give value for money because of inadequate definition; state of the art advances have taken place to which the particular contractor made no contribution but because of which he nevertheless reaped a reward; etc.;

(b) the arrangements have tended to become very elaborate in attempts to relate incentives to, for instance, large numbers of PERT steps involved in complex programmes. In consequence, some of the provisions are difficult to comprehend and are a potential source of litigation in future years. Even in an apparently straightforward case of an incentive for in-service reliability, the contractor disputed non-payment of the reward on the grounds that the Service technicians were of poor quality;

(c) delivery bonus schemes have sometimes given rise to unnecessary payments by the Government for delivery ahead of target, and consequential costs of storage, etc., because the relationship to associated programmes had not been foreseen, for example, other components of the system were not available, test facilities were not available, test facilities were occupied with other work; and

(d) a successful multiple scheme has to achieve an optimum balance between cost, performance, and delivery. The theory is that the incentive structure should compel decisions between these aspects that are in line with the Government's objectives. It is not easy, however, to ensure that the most profitable trade-off decision for the contractor coincides with that which the Government would prefer. This is particularly the case on a cost plus incentive fee contract where, because there is no maximum price, the contractor may incur large cost overruns in seeking marginal improvements in order to gain a performance bonus. In this situation, the Government might prefer a more modest but nevertheless acceptable performance at significantly lower cost. Moreover, changing conditions during the contract (for example, in capacity, through loss or addition of business) may affect the operation of the original incentive provisions. Because of the difficulty in coping with these situations it has now been decided that where a contractor optimises profit by ignoring the Government's stated objectives the fact will be recorded against him under the Contractor Performance Evaluation Program and this may adversely affect his selection for future contracts.

234. In view of these hazards, performance and delivery incentives are now being approached by the Department of Defense in terms of their inter-relationship with each other rather than treating each of the elements of cost, performance, and delivery separately. They have recently developed techniques using computer models for determining what the effect of 'trading-off' between these elements will be on a contractor's profit or fee. Using these techniques, the Department of Defense is able to evaluate the various combinations of performance and costs in order to determine their relative value to the Government and, thus, more closely relate the contractor's fee to the preferred combinations of performance and cost. An extensive training programme is being organized which will emphasize the more advanced evaluation and 'structuring' procedures developed as a result of the experience gained with the earlier incentive contract arrangements.

The relevance of U.S. experience to U.K. conditions

235. The types of incentive contract used in this country are similar to those employed in the United States, the cost plus incentive fee and fixed price incentive types being classed together here as target cost contracts. The basic techniques used in incentive contracting are much the same in both countries, although they have been greatly developed in the United States and published in various Departmental handbooks[3].

236. The general policy of employing cost incentives on development produces major benefits through the need to define specifications and to plan work carefully in order to arrive at realistic estimates acceptable to Government and contractor as a basis for the incentive contract. The view that incentives are essential to achieve effective management control of costs is widely held in the United Kingdom as in the United States, and is reflected in the policy of the Ministry of Aviation to use incentive contracts for development work wherever possible. However, whilst the U.S. Air Force placed 66% by value of its research and development work on incentive terms in 1964, (see paragraph 225) the value of Ministry of Aviation incentive contracts (excluding fixed profit fee cases) amounted to some 30% of the total in that year. A major difference is that the target cost type of contract is most often used in the United States for development work, but has been used only occasionally in the United Kingdom. It requires more administrative effort than a fixed price contract since, in addition to price investigation and negotiation at the outset, costs have to be monitored during the course of the work and have to be taken out on completion. But, except for small value work, the target cost contract offers the best arrangement for providing the flexibility needed to deal with the varying degrees of confidence in project estimates, for the sharing of risks between contractor and Government, and for effective rewards and penalties.

237. None of the systems that have been through the Contract Definition procedure are yet in service and appraisal by the Department of Defense of the incentive contracts placed for development has only recently been put in hand. At this stage, therefore, an analysis is not available over the whole range which provides proof that the advantages claimed are being achieved. Whilst examples are quoted which demonstrate dramatic cost savings, measured against target costs, there is no way of knowing what the results would have been on a non-incentive basis. The most convincing evidence to date is perhaps provided by particular

instances of the impact on contractors' management in reducing overheads, eliminating waste, etc., which Departments through their strong force of plant representatives are in a good position to observe and evaluate.

238. The American methods of achieving a situation in which incentive contracting can be employed for development work, as described in Chapter 8, offer a useful guide to the way in which increased use of incentives might be obtained in this country. However, the acceptance of the incentive policy by American industry, and the Department of Defense's insistence on this policy, have to be viewed against the following background:

(a) the American aerospace industry operates in a much different environment from that in this country. The number of very large companies in the United States in the aircraft, engine, missile, and electronics fields is considerably greater than the number of companies with similar interests in the United Kingdom, and the U.S. companies are conditioned to operate in fierce competition and to accept increasingly demanding standards from the U.S. Government, in order to maintain or enhance their position in the competitive environment. The rewards of success in American defence contracting are very great, particularly in view of the large scale production orders which normally follow development. These potential prizes spur companies to greater efforts when formulating proposals for development, and the Department of Defense is exploiting this situation in a determined effort to improve efficiency; and

(b) U.S. contractors concerned with major development work, being very large organizations, are in a better position to absorb losses or suffer penalties. Moreover, losses or meagre profits on development can be cushioned by the gains from the large production runs which follow.

239. A danger to American development projects, stemming from the strong competition for contracts, is the tendency of firms to 'buy in', which may subsequently result in them sacrificing quality, whilst formally meeting the specifications, in order to keep within prices. Performance incentives provide a means of attempting to withstand this pressure. For cost reimbursement type contracts without a maximum price, use of performance incentives seems wrong in principle, unless the incentive reward is paid only for specified combinations of performance and cost, because there is in any event a strong tendency for firms to stress quality improvement rather than cost reduction. Instances of incentives on American lines for performance and delivery are rare in Ministry of Aviation contracts, although liquidated damages are sometimes provided for late delivery. Although the American experience indicates that we should be cautious in using such incentives, there seems scope for application in this country:

(a) of performance incentives in development contracts,

    (i) as a counterweight, if a strong cost incentive can be applied, to combat any tendency to skimp quality; or

    (ii) where performance better than that necessary to meet a specification achievement is highly desirable; and

(b) of delivery incentives, particularly for hardware in development contracts and for production work,

    (i) where it is important for agreed dates to be met (a reduction in price for failure would normally be appropriate here, but no bonus would be offered for early delivery); or

    (ii) where there are significant advantages to the Department in improving on agreed dates, or where emphasis needs to be placed on achievement of target dates.

240. There are not, however, the same compelling reasons for firms in this country to accept incentive contracts for development, and similar hedges against the risks are not available to them in that production runs are comparatively small. The kind of loss that a major

American firm could absorb would either bankrupt a U.K. firm or entail Government assistance to keep it in business. Thus, there is not likely to be great scope in this country for incentive contracts on large development projects which involve significant technical risks. Substantial scope remains however in respect of the considerable number of large and small projects without such risks. In view of the smaller production runs, and thus the more significant part played by development in a company's business, the fixed fee for profit is more likely to have an incentive influence on U.K. firms, since a very low profit return could cause serious difficulty.

Conclusions

241. This account of recent American practice and experience suggests that the defence Departments of both countries are agreed that two of the essential conditions for the successful negotiation of an incentive contract are the existence of firm and detailed technical specifications, including test schedules, and realistic estimates of cost. The United States defence Departments have recently been able to achieve a greater measure of incentive contracting for development work than has been possible here, principally because of the improved procedures they have introduced for planning and controlling development, and because they have been able to maintain competition between firms up to the stage where incentive contracting becomes possible and thus oblige them to accept the incentive policy with its attendant financial risks.

242. The feature of the American procedures which has contributed most to ensuring that the essential conditions noted above are fulfilled before a commitment is made to go forward with full development is undoubtedly the 'building block' approach, under which component development is carried out as a preliminary stage, often in anticipation of future needs. The technical risk involved at the full development stage has by this means been reduced to a level at which it is acceptable to the contractor and the defence Department in the context of incentive contracting. The Defence Research Committee in this country have recently endorsed the principle that more 'component research' of this nature should be undertaken here in advance of specific requirements. Nevertheless it seems clear that the very large American expenditure on such work cannot be matched.

243. The possibilities of using competition as a means of inducing U.K. firms to undertake incentive contracts are small particularly on major projects. In many cases, for example, where a proposed new equipment is an improvement of an existing equipment or one already under development or where expertise is concentrated in one firm, competition does not exist at all. Where it does, it has usually been limited to the feasibility study stage because it has been felt that the pressure on the technical manpower and financial resources available for defence was too great to allow competition to be taken even to the completion of the project study stage. As we have already pointed out, the state of definition at these early points is normally too uncertain to allow the preparation of either a detailed technical specification or an estimate of cost which is sufficiently realistic to form the basis of an incentive contract. In consequence the scope for the introduction of incentive arrangements at these stages is bound to be extremely small, particularly on the more costly projects involving a significant technical advance.

244. The prospects of extending the scope for incentive contracting will, we think, be improved on the smaller or technically less risky projects by carrying out project studies with the greater thoroughness we recommend in Chapter 11 and by undertaking in the course of these studies experimental work aimed at better definition. In the case of the larger and more risky projects there may perhaps be more opportunity for negotiating incentive contracts for the last phase of development, corresponding to the American Engineering or Operational Systems Development categories, if this phase were to be made the subject of a separate contract with the company undertaking the earlier work. The Society of British Aero-space Companies in recent discussions on the possibilities of extending incentive arrangements stressed that on development contracts, where precise definition was not possible at the outset and where achievement could not be predicted, contractors are chiefly concerned to recover their costs. They said, however, that they would have no objection to the negotiation of suitable cost incentives for the later stages of development when the definition of requirements became feasible, the future course of development predictable, and the cost could be estimated

reliably. On the other hand they showed little enthusiasm for incentives on features such as performance and delivery although the way was left open for the Ministry of Aviation to propose suitable schemes in individual cases.

245. We entirely support the present policy of seeking incentive arrangements for development work wherever possible. Although performance and delivery incentives have considerable merit in certain applications, their use entails additional technical and contract effort and in present circumstances it would be too ambitious to attempt to introduce them generally. We feel therefore that it would be better at this juncture to concentrate on improving techniques in the use of cost incentives and on gradually extending their application. Accordingly we recommend that the circumstances of each project should be examined by the technical staff, in consultation with the finance and contracts branches, before a project definition contract is placed and, unless it is clear that the necessary pre-conditions for an incentive contract will not exist, the contractor should be required as one of the outputs of this phase to put forward proposals for incentive arrangements for any subsequent full development contract or for such parts of the programme as appear suited to this form of contracting. The supply Department will then need to decide in each case whether incentive arrangements are appropriate and the stage at which they should be introduced.

246. We feel that a policy of employing incentive schemes will be of some help in stimulating industry to produce better estimates at the earliest possible stage, particularly on projects of low risk and comparatively small cost. We do not think, however, that we can look in this direction for a major contribution towards better estimating in the area where it is most needed, that is, the technically advanced weapon system requiring the concurrent development of a number of its major component parts and their integration into an effective whole. For the means of alleviating this problem, we must look elsewhere.

REFERENCES

1. Report of Ministry of Aviation Contracts Division Study Group No. 1 Incentive R and D contracts, June, 1965.
2. Report on Visit to U.S.A. by Under-Secretary (Contracts) to study Incentive Contracting for Defence Procurement, October, 1965.
3. For example, Department of Defense Incentive Contracting Guide, 1965.

CHAPTER 11

Our Proposed Changes to the Procedures

Introduction

247. The decline in the proportion of the gross national product devoted to defence has coincided with an increase in the technical complexity of modern weapon systems. This has thrown an added burden on the Services in terms of the organization and facilities which they must provide to ensure the serviceability and operational effectiveness of the limited number of equipments which they can now afford. This has led to the placing of more stringent requirements for reliability and ease of maintenance on the Ministry of Aviation, which in turn has increased the scale and cost of the development task.

248. The increasing complexity of modern equipments and of the services required to support them, the high cost of their development and procurement, and the associated problems of logistics and retraining, have meant that re-equipment can only take place at infrequent intervals, each new generation representing a considerable technical advance on the last. Moreover, with our limited resources, we are not able, as is the United States, to undertake continuous 'state of the art' development of 'components' and sub-systems on a wide front to ensure that major areas of uncertainty likely to arise in future projects have been explored; nor can we pursue alternative lines of development in order to pick the more successful. In consequence, we have not the same solid basis of experience on which to proceed to the development of 'components' or sub-systems for incorporation in new equipments, nor can we have the same assurance on the reliability which such 'components' or sub-systems are likely to achieve when developed. As we have already noted in Chapter 10, the Defence Research Committee has recognized this danger and has accepted in principle the need to expand research and experimental development work on 'components' in advance of specific Staff Requirements, and further consideration is being given both to the range of programmes which should be undertaken and the criteria by which they should be judged and controlled. Nevertheless, although work of this kind is necessary to ensure that development proceeds in balance along a broad front, it cannot cover the whole field. We therefore think it wise to assume that many new projects will continue to press against the limits of engineering and scientific knowledge in some areas and to require the use of relatively untried techniques.

249. In these circumstances, we do not foresee any lessening of the difficulties which now surround, particularly in the early stages, the preparation of programmes and cost estimates for advanced development work in the defence field. Nevertheless, we believe that by adopting the procedure we propose in this chapter, these difficulties can be mitigated to some extent and that more realistic development programmes and cost plans can and should be obtained before the supply Department becomes committed to full development.

Need for better project definition and later decision point

250. As we have shown, the information and specifications which arise from the project study stage under the present procedures are in general inadequate to provide a well-founded Development Cost Plan on which to base a major project and to seek approval for full development. To be satisfactory such a plan must fulfil the following conditions:

(a) it must fully define the constituent tasks;

(b) it must clearly identify significant 'end events' throughout the project timescale, together with the work and trials leading up to them which if achieved will provide evidence to the supply Department that each stage of development has been completed successfully;

(c) the constituent tasks must be broken down into smaller discrete units of work, each with its own technical objective and budget, sufficient in number and frequency for close monitoring and control and against which technical and cost progress can be judged; and

(d) it must provide a datum for the evaluation of any subsequent changes proposed.

251. Unfortunately, as we have explained in Chapter 7, the present project study does not go far enough to identify and explore the difficult areas of design, and to establish the successive steps necessary to achieve the development objectives with the precision which the above requirements demand. As a result, the Development Cost Plan which emerges does not provide the solid and clearly defined base that is needed. For this, greater depth of investigation is necessary and the present point of decision must be moved, at least for the larger projects and those involving above-average technical risk, to the stage where the first well-founded synthetic estimates of development cost, based on the cost of the constituent discrete units of work, and of unit production cost become available.

252. Although it is true that there is not a definite point in the development cycle when an estimate can be said to become 'synthetic'—and indeed such an estimate, as we have seen in Chapter 7, can consist of a combination of estimates arrived at by different methods so that the nature of a synthetic estimate itself will vary, depending on the degree of project definition achieved at the time it is made—nevertheless it does appear that an important change takes place in the character of an estimate by the end of an initial period of development. This may be some two years or more from the start of the present form of project study in the case of a major weapon system. Because of the difficulty in assessing this point in a particular case, it is important that the extent of the work to be undertaken in this initial phase should be agreed with the contractor as sufficient to identify the problem areas and to explore the development tasks to the required depth. Moreover, since the amount of work required from the start of a project study before this situation is reached may involve expenditure of up to 15% of the estimated total development cost, and as both the supply Department and the contractor will be more deeply committed than at the end of the present type of project study, we believe that the supply Department must be closely associated with the contractor's study throughout this period, so that it may be aware at once should circumstances arise which throw doubt on the justification for continuing.

Proposals for more detailed project definition

253. For the larger and technically more advanced projects we are, therefore, proposing that the present project study should be replaced by a new phase to be known as Project Definition, which would be in two stages. This would follow the feasibility study, which should continue to be undertaken as at present. We consider, however, that the feasibility study should not be restricted to theoretical work but should also be permitted to include whatever experimental or engineering work is necessary to identify the scientific and technical problems involved and to assess whether they can be solved. In this connection we note that whilst such work is not at present specifically excluded from feasibility studies as currently defined in Ministry of Aviation instructions[1], nevertheless, it is stated elsewhere that a feasibility study is not normally expected to involve any experimental work or engineering[2].

254. It is of the essence that Project Definition must be a more searching investigation of the proposed project than is at present undertaken during the project study stage, and that it should lead to the highest standard of definition possible at that point. Project Definition would not normally be competitive and it would be used to explore the areas of technical uncertainty and to evolve detailed specifications to form a basis for more detailed and realistic estimates of time and cost and for a decision on whether to proceed with development to completion. It would include whatever initial design and experimental work was necessary. It is important that sufficient time and money be allowed for these tasks and that there should be no question of squeezing the effort required into a purely arbitrary time and cost scale. Both stages of Project Definition would be covered by a single contract, and the second stage would follow on without a pause after the first, unless the results of the first stage led to a decision to discontinue the project.

255. As we have seen in Chapter 6, no contractor can be expected to prepare an adequate Development Cost Plan unless he is given a clear statement of the requirement he has to meet. Project Definition must, therefore, start with such a statement: this would normally take the form of an unambiguous—though not necessarily final—Staff Requirement defining the performance and the operating features required and the conditions under which the equipment will have to function. Where there are alternatives, whose choice depends on the outcome of further study, these should be clearly stated so that their implications can be fully examined. Where possible, the contractor should be given a production cost aim and an

indication of the importance attached to the performance and operating features called for, and of their relative priorities. Only in the exceptional case when the supply Department retains the Design Authority function would we expect the contractor to be given a statement in technical terms of the aims to be achieved rather than a Staff Requirement as a basis for Project Definition. Even then, such a statement should not be so worded as to inhibit the contractor from putting forward alternative proposals of his own for meeting the operational need.

256. A time-table for Project Definition should be agreed with the contractor which would set out the dates by which he would aim to complete the main stages of the work and to provide the documentation required. A contract, normally on a cost re-imbursement basis, would then be placed providing for stage-by-stage payments when the appropriate work had been completed and satisfactory documentation had been received. Completion of the work to the programme and the preparation and submission of documentation to the necessary standard will impose a tight discipline both on the contractor and on the supply Department who, in conjunction with the user Department, will have to provide advice as required on the assumptions to be made and on the choice of options where these arise. It is important, therefore, that the user Department as well as the supply Department, should realize and accept the obligations and restraints which this imposes.

257. The first stage of Project Definition (PD.1) would correspond broadly with the project study envisaged by the Zuckerman Report. At the end of this stage, the contractor would submit his proposals for meeting the requirement indicating any 'trade-offs' (for example, cost against performance, cost against reliability) which might be desirable. These proposals would include:

- (a) a first draft of a comprehensive Development Specification comprising the following specifications:
    - (i) Performance,
    - (ii) Development Trials,
    - (iii) Engineering Characteristics;
- (b) a first Development Cost Plan containing:
    - (i) a development programme for the project, including an outline PERT network,
    - (ii) an associated cost plan,
    - (iii) an estimate of unit production cost;
- (c) a description of the contractor's proposed project management organization;
- (d) the arrangements proposed for the co-ordination of activities of, and liaison with, other supply Department contractors and sub-contractors; and
- (e) incentive contract proposals.

The Development Cost Plan would necessarily contain estimates on a mainly comparative or parametric basis, although attempts would be made, wherever possible, to distinguish between those areas of design which were technically similar to those in previous projects, and those which represented a major technical advance, and to indicate the likely reliability of the associated costs.

258. By the end of PD.1, decisions on major 'trade-offs' should have been taken and the Staff Requirement should have been firmly established enabling the contractor to proceed during the second stage of Project Definition (PD.2) with more detailed design and any further associated work necessary to refine and consolidate the data produced during PD.1. From this PD.2 stage would emerge a Development Specification whose constituent specifications would be in precise terms: the Performance Specification would define fully the performance being offered; the Development Trials Specification would detail the tests (and test results) proposed

as demonstration that each stage of development had been satisfactorily completed; and the Engineering Characteristics Specification would describe in detail the engineering characteristics of the hardware to be developed. Where information might be incomplete pending further development, assumptions would be made and clearly stated to provide a basis for the establishment of costs and for the evaluation of subsequent changes. Accompanying the Development Specification and forming the second Development Cost Plan would be a development programme and related cost estimate, together with an estimate of unit production cost. The PERT network supplied as part of the Development Cost Plan would be in greater detail than at the end of PD.1. The Development Cost Plan arising at the end of PD.2 would be based on estimates prepared on a mainly synthetic basis and arrived at for the most part by analysis of the constituent tasks into their work, material and facilities content.

259. It is the essence of our proposals that, throughout the feasibility study and Project Definition stages, the areas of technical uncertainty are progressively reduced, the programme being defined in detail for the period immediately ahead and in broader terms for the remainder. This philosophy is also followed throughout the development, so that the programme is regularly updated to provide the necessary degree of detail for the ensuing twelve months. Thus, by the end of PD.1, it should be possible to have defined and made a preliminary exploration of the areas of uncertainty, and to have established a detailed plan for the further work required on them during PD.2, and a broader plan for the remainder of the project. By the end of PD.2, all the uncertain areas should have been explored and a programme of future work defined, again, in more detail for the period of twelve months ahead than for the remainder. It must, however, be recognised that in some areas the definition will necessarily be tentative and that changes in engineering, trials, and even performance requirements may subsequently emerge. Nevertheless, the information which arises at the end of PD.2 should not only provide the basis for the estimate on which full development approval is sought, but a detailed programme against which progress can be monitored and work and cost controlled. Moreover, by providing clear and explicit specifications against which the work and cost content of the programme can be judged the risk of insidious change, and consequent cost increase, is reduced.

260. To enable the contractor to draw up his PERT networks during Project Definition, it will be necessary for the supply Department to provide information on decision points within Government control and on which firms should plan, for example, the dates to be assumed for firm decisions to proceed with, or discontinue, the project, and for the issue of contracts. Details of the proposed Departmental organisation for managing the project should also be supplied. During PD.1, the supply Department should discuss with the contractor the form of contract to be adopted should the project proceed, and invite his proposals on incentive arrangements and on his relationship with other firms contributing to the project, so that negotiations on the development contract can begin during PD.2. In this connection, it is important that the arrangements for the co-ordination of a project should be established at an early stage so that a contractor is aware of the basis on which he should plan. We believe that, with some exceptions, the overall co-ordination of information on a major project involving a number of supply Department contractors should preferably be left to a main contractor nominated for the purpose as is now the usual practice. However, even where this may be desirable it may not be practicable; as in the case of a firm called upon to supply commercially confidential information to another acting as co-ordinating authority who may, in another situation, be a competitor. In these circumstances, the supply Department may have to accept responsibility for co-ordinating information, at least on cost, in respect of the main constituent parts of the programme, and for the operation of the PERT network for the project as a whole. The case for this is strengthened where many of the inputs at this level depend on the completion of activities within Government Departments or Agencies. Moreover, it must be recognized that although a main contractor may provide a co-ordinating service, he cannot exercise control of equipment where this is being developed under direct contract from the supply Department since he has no responsibility for this.

261. It may be difficult, but should not be impossible, to estimate the cost of a contract covering the two stages of Project Definition. However, the report at the end of PD.1 would, if necessary, provide an opportunity for submitting a revised estimate for the cost of the remaining part of the contract. This report would also contain the best estimate possible at this stage of the cost of proceeding immediately to full development to completion and alternatively estimates for development for a limited period pending a final decision. At this

point in time, that is, at the end of PD.1, which would be about the same as the present point of decision as envisaged in the Zuckerman Report, the Government would have a number of options. These would include the option:

(a) to cancel the project forthwith;

(b) to continue with Project Definition and to defer a decision about full development until the proposals at the end of PD.2 are received;

(c) to continue with Project Definition and, in aparallel, to authorize the purchase of long-dated materials and bought-out items; together with the manufacture of equipment necessary to permit a smooth transition at the end of PD.2 if full development is then approved. This authorization would cover a period extending (say) six months after the completion of Project Definition;

(d) to continue with Project Definition, but in addition to authorize work as if a decision to proceed to full development had been taken. This authorization would cover a similar period to that at (c), but would normally allow a faster build-up of effort and commitments; or

(e) to place a development contract to completion at once.

262. A procedure on these lines would introduce a much needed element of flexibility into the present over-rigid arrangements It does not impose new development burdens on contractors, but seeks to take advantage of the fact that the period of greatest uncertainty in a development programme normally coincides with the period of lowest spending, and of the stage reached in the normal evolution of a project at which a reasonably well-founded development programme and cost estimate can be established, in order to obtain at this stage, through a more explicit and precise process of definition than in the past, a better understanding of the nature and scope of the task ahead and its financial implications We do not view this Project Definition phase as additional to, but rather as proceeding in parallel with, and forming part of, the normal process of initial clarification and design.

263. Nevertheless, the practical difficulties in its way must not be under-estimated. A design team cannot be built up to a point at which a well-founded estimate becomes available and then stood down for an indefinite period while decisions are taken and, if they are affirmative, reintroduced as design gets under away again. It is for this reason that we attach considerable importance to our proposal that, pending a decision on the proposal submitted at the end of PD.2, the contract arrangements should be such as to ensure continuity and the orderly build-up of development. Unless, therefore, there are evident and serious doubts about the validity of the assumptions made earlier about likely cost and timescale, we expect course (c) or (d), or some variant of these, to be the normal method, so that the contractor, whilst the Government is considering his proposals, can continue at the planned rate laid down in the programme, or at a rate agreed with the technical branch. Failing this, momentum will be lost and extension of the timescale, and most probably the cost, will be inevitable; moreover, delays may be taken as opportunities for introducing design changes and the duration and cost of the programme may then be further extended.

264. In practice, work in different areas of a project does not proceed uniformly; preliminary experimental work, initial design, and the manufacture of prototype items for test may all proceed in parallel. The process of development is not a simple sequence of design, construction, and testing of prototypes, but a complex advance on a broad front though with design effort rising to a peak, and falling away as drawings become increasingly translated into hardware. It is, therefore, unrealistic to expect to be able to separate a project into successive time periods each covering one of a series of discrete categories of work. Even if industry were able and willing to make such an idealized procedure work, it would add considerably to the (already long) development timescale. Contractors are naturally concerned to terminate the project study phase quickly and obtain a full development contract before they begin to commit largescale effort to any project. They are also unlikely to be willing to accept the longer exploratory stage we now propose if there is not a concurrent authorization during PD.2 of whatever work is required, including if necessary a start on the manufacture of prototypes, to maintain the momentum of the project and ensure a smooth transition to full development at the earliest possible date.

265. Nevertheless, where the design effort involved is small in relation to the total design resources of the firm, the problem may not be too intractable from the industrial point of view—it may be possible for the team to be absorbed into or replenished from other projects. Again, in the case of some equipment, it may be quite practicable to go some way towards completing the initial design and experimental stage before any prototype metal has to be cut, without substantially increasing the development time cycle.

266. This emphasizes again the need for flexibility in approach. There has been widespread concern lest the application of the procedures proposed in the Zuckerman Report should cause excessive delay. Hence, although our present recommendations may be regarded as an extension of these procedures, it is important that they should not be interpreted over-rigidly, particularly in the smaller and less ambitious projects when the costs in absolute terms are likely to be low, and that no greater definition of the project and its programme is sought than is warranted by the financial risk involved. An over-insistence on demonstrating that each of a succession of well-defined steps has been completed satisfactorily before proceeding to the next may well reduce the chances of equipment being available in the right quantities and at the right time. As a result the user Department may have to continue with obsolescent equipment, and to re-provision spares and arrange reconditioning programmes at considerable additional cost. Inability to introduce equipment at the right time may also seriously increase the cost of its development to the supply Department. Not only will a longer programme almost inevitably lead to an increase in cost, but equipments may be so delayed that they become less attractive on the export market with the result that sums arising from the levy on production sales abroad, which might otherwise offset part or all of the development cost, are reduced or lost.

267. We therefore propose a simplified procedure for smaller projects. This involves a single Project Definition stage, intended to give a degree of definition similar to that obtained at the end of PD.2 on a large and complex project. The duration and cost of this single stage will depend on the complexity and novelty of the project. With a relatively simple project involving only a limited technical advance, it may be reasonable to take decisions to proceed to full development at the end of a period comparable to that envisaged for the present type of project study, provided that the studies are carried out with sufficient thoroughness and allow for adequate experimental work. Indeed, for some cases a decision may be desirable even earlier (particularly if by developing an improved capability for assessing costs by comparison with past projects the realism of the supply Department's own estimates can be increased), because some smaller projects would appear to be unnecessarily penalized by the elaborate nature of the present procedures. In a marginal case of this nature, Research and Development Board and Weapons Development Committee approval to go to full development might be given subject to review at the end of a predetermined period, say, twelve months or whatever lesser period the circumstances justified.

268. Nevertheless, although we consider that a single rigid procedure for all types and sizes of projects should be avoided, full development should not be authorised on major technically advanced projects until the main uncertainties have been resolved and a well-founded programme and estimate have been prepared which can be used for control purposes. We take this view because experience shows clearly that once full development starts on the basis of an unrealistic estimate, realism emerges only gradually. Moreover, as we have shown, the Development Cost Plan which emerges at the end of the present style of project study is an unsatisfactory control document and there is no way of compelling a dilatory contractor to prepare the required review documents both thoroughly and expeditiously. Accordingly, a major project will have built up considerable momentum before there is an adequate mechanism of control and an adequate basis on which to take decisions. It is for this reason that we consider it important that the contract arrangements should ensure that the contractor has a financial incentive to provide the documents required at the end of PD.1 and PD.2 in accordance with the agreed timetable.

269. For similar reasons, we would emphasize the need for the form of project organization and the methods of programming, budgeting, and recording technical and cost progress to be established and clearly defined before full development of a project starts. Attempts to devise or revise procedures at a later stage are likely to cause confusion and make it difficult to reconcile progress achieved with the original plan. Moreover, once a contractor has received authority to proceed with full development it may be difficult for the supply Department to insist on changes in organization without laying itself open to charges of delaying the project.

270. We have referred in Chapter 7 to the need for improved project estimating and management methods and for a more disciplined and professional approach to these. An important weakness in many companies is that the cost allocation and cost collection systems were originally devised mainly to allow individual claims for payment to be prepared and only incidentally, if at all, as an instrument for the physical and cost control of projects or as a means of collecting information for estimating the cost of future projects. It is, however, becoming clear to most contractors that the proper estimating and control of development work requires an analysis of effort and cost both by functional department and detailed description of work, and that figures will need to be prepared in more detail than in the past. By this we do not envisage a meaningless mass of petty figures, but rather the minimum necessary to compare cost with progress in each main area of the project, and to provide the basic information for future estimating. It is, however, important that the procedures that are now proposed should be extended through to main sub-contractors. Deficiencies, wherever they occur, may jeopardize a project, and timely returns of information on work and cost progress to the main contractor are essential if his control is to be effective and he is to fulfil his obligations to the supply Department.

Handbook of Procedures

271. The Handbook of Procedures at Appendix M defines the content of Project Definition more fully and describes a set of integrated procedures for the programming, estimating, and control of development projects, which contractors are recommended to follow. We hope that this will contribute towards the correction of the weaknesses that have been revealed in some of the present methods. For many of the actions by contractors there need to be complementary actions by the supply Department and a check list of the more important requirements laid on the supply Department's project staff by the Handbook is included as Appendix N.

272. It may be argued that for major projects costing many millions of pounds, the Handbook does not go far enough. On the other hand, it is important not to introduce procedures which are unnecessarily elaborate and which cost more to operate than they yield in increased efficiency. We have therefore thought it right, as a first step, to base it on procedures which though they may now be applied only on isolated areas, at different depths, and with differing degrees of effectiveness, are already in use in the defence field. It can, therefore, be supported from current practice. However, we look on this Handbook only as a starting point. We envisage that it will have to be revised and improved as knowledge and experience grow, and that machinery for this purpose may have to be created.

273. Effective procedures for programming, estimating, and controlling development projects are an essential part of efficient management. To the extent that present management procedures fall short of those laid down in the Handbook of Procedures additional outlay may be required in industry to bring them up to that standard. Even so, we do not consider that the cost of the additional staff and facilities will more than marginally affect the cost of a major development project. Indeed, in addition to providing greater assurance that projects once they have reached the stage of full development will not subsequently be cancelled, thereby reducing the risk of large nugatory expenditure, we believe, though this is necessarily difficult to substantiate, that the savings arising from the introduction of the new procedures will more than offset the expenditure incurred. Moreover, as the cost of a development programme is a reflection of its duration and the level of staffing and facilities committed to it, the larger and more complex the project the more worthwhile the possible savings. The procedures we now propose, by defining more clearly the inter-relationships of areas of effort, should enable resources to be employed more effectively, and redirected to areas of greatest need in the light of the workload revealed as the programme proceeds. They should, therefore, reduce rather than increase the timescale of development and in consequence its cost.

274. However, the consultants' studies have shown that such procedures cannot be introduced and become effective quickly and that several years may elapse before the necessary changes to a firm's organization are complete and staff are sufficiently versed in the new techniques; moreover, staff must be receptive to them and trained in their use. We have referred in Chapter 5 to the need for the training of officers of the Ministry of Aviation engaged in project management, and would draw attention to the need for similar training in industry,

possibly through joint courses arranged with the Ministry. We envisage that the first priority should be given to improving the efficiency of the supply Department's own project officers, through training courses based on the Handbook of Procedures, and arrangements are now being made to this end. Once this has been achieved, the emphasis can be placed on encouraging the acceptance and the use of the Handbook by the firms with which the project officers are dealing.

Programme reserves and general contingencies

275. The Handbook of Procedures includes at sections 3.3.11 and 4.3.5 some proposals on how reserves of effort, time, and cost should be provided within a programme to take account of areas of technical uncertainty, and in forwarding his Development Cost Plan to the supply Department at the end of Project Definition a contractor should confirm that it has been conducted in sufficient depth to enable the technical uncertainties to be assessed and a soundly based programme and estimate to be prepared; or should indicate where, in what respect and for what reasons his Development Cost Plan may be open to doubt.

276. If this approach were adopted we would recommend the abolition of the present procedure[3] whereby the Ministry of Aviation invites the Managing Director of a company preparing a Development Cost Plan to say what further general contingency, if any, should in his Company's judgment in the light of experience be added to the Development Cost Plan estimate. This would appear to imply an acceptance of a lack of realism in a firm's programme and estimate which is contrary to the concept of the procedures we are now proposing. If the addition of a general contingency is necessary, this should be shown as part of the Development Cost Plan at the time of its submission and its inclusion should be justified. A Development Cost Plan must stand or fall on its own merits as a comprehensive statement of the programme required to attain a given objective and of the costs required to implement it.

277. For the same reason, we also recommend that the use of Confidential Policy Estimates[4] and Confidential Target Dates[5] should be abolished. Experience has shown that sooner or later the contractor becomes aware of the supply Department's confidential estimates of time and cost (which are invariably more pessimistic than his own) with the result that he knows by how much his estimates can rise, and his timescale can slip without incurring the risk of cancellation. We have already noted a tendency for contractors to prepare over-optimistic estimates: this is encouraged by the knowledge that the supply Department will add a further sum before seeking policy approval. We accept that, in the early stages of the project, the supply Department will need to make its own confidential assessment of probable time and cost. For example, at the feasibility study stage, lacking a full definition of the task and in the absence of a well-founded estimate from the firm, the supply Department must make its own assessment, based on the best conclusion it can draw from past experience. But, as definition of the task increases, so should the value of the firm's estimates. We consider that, with the more searching definition phase we now propose, by the end of PD.2 the contractor's figures, including all necessary allowances in the form of reserves of effort, time, and cost relating to specific areas of work, should be regarded as final, and that both the contractor and the Project Director should be prepared to stand or fall by them. If the Project Director is not satisfied with the contractor's estimates at this stage, he should continue discussions with the firm until agreement is reached.

278. From this, it will be realized how important it is that staff responsible for project planning and estimating, whether in the supply Department or at the contractors should be convinced of the need for estimates which are both fully realistic, inasmuch as they make sensible allowances for work which past experience has shown is likely to be required, and reasonable in the light of the stated objectives. It must, moreover, be evident to all concerned that the determination to achieve such estimates exists at the highest levels, and there must be an awareness that, as history has amply demonstrated, there is nothing to be gained in the long run by over-optimistic assumptions about development programmes and estimates.

279. We realize that there will be a need for some time to come, at least until procedures comparable to those recommended in the Handbook of Procedures are in general use and confidence in their validity has been established, for the supply Department to continue to make its own confidential assessment of probable time and cost. Even when this position has

been reached, it will still be necessary for the supply Department to allow a contingency for the type of major setback which sometimes occurs in a development programme. We suggest, however, that contingency margins should not be permitted for this purpose on individual projects. A single line entry should be used to cover the whole field of project development.

280. In making its submission for approval to the Research and Development Board and the Weapons Development Committee, following receipt and scrutiny of the Development Cost Plan, the supply Department should give its confidential assessment of the realism of the contractor's proposal and should confirm that the studies have been carried out to the depth envisaged by the latest procedures and appear soundly based. If, for any reason, it is considered that particular areas have been insufficiently studied, this should be stated explicitly, the areas identified and the possible repercussions on the programme described.

Relationships between the supply Department and industry

281. We have already indicated the need to define more clearly the requirement to be placed on the contractor and to prepare a plan at an early stage of a project to which both Government Departments and industry will be expected to work. This plan should cover not only key technical events such as the supply of critical embodiment loan equipment but also key administrative events, for example, the placing of production contracts. It is important that all Departments (including the Treasury) should accept in parallel with industry the disciplines and constraints which this entails. It is essential that, at the end of the feasibility study, PD.1, and PD.2, respectively, every effort should be made to assess the worth of the contractor's formal report quickly, and to reach a decision on whether or not to proceed with the next step. If the supply Department's officers have maintained the necessary close liaison with the contractor, they will be aware of his technical proposals, his programme, and its probable cost long before his formal submission is made, and the intelligent use of this advance information should enable the subsequent formal decisions to be made promptly.

282. While we appreciate that policy considerations may affect the supply Department's freedom of action, nevertheless we do not believe that enough is being done at present to work to a concerted plan and to eliminate delays. For example, there is evidence that the individual Ministry of Aviation technical, finance, and contract branches do not always work sufficiently closely together to achieve the necessary unity of purpose. This evidence underlines the criticism made by some contractors that responsibility within the Ministry of Aviation is unduly fragmented and that its arrangements for the co-ordination of major weapon systems are unsatisfactory. Some action has already been taken by the Ministry to improve the position and the recommendations we have made in paragraph 172 about the issue of an organization document on all major projects should lead to a further improvement.

283. We have noted those aspects of the Plowden Report[6] which are relevant to our activities and in particular the comment[7] that the Government exercises financial and technical control which duplicates the industry's own control and hampers efficiency. We believe that the proposals we now put forward are not inconsistent with what the Plowden Committee would like to see achieved in this area[8]. It is intended that during the Project Definition phase, very close liaison should be maintained between the supply Department and the contractor and that the programme should be defined precisely. The application by industry of the procedures we propose should, therefore, once the Project Definition phase has been satisfactorily completed, reduce the need for day-to-day participation by the supply Department during full development as the position on the project should be self-evident from the regular information returns which are an essential part of an efficient management procedure. These should ensure that the up-to-date technical and financial situation is continuously available. Thus, once a programme has been firmly established, the need for continuous oversight should be reduced and only in the event of significant or incipient variations—either technical or financial—from plan as revealed by the returns, should Government interference in the project be necessary.

284. Nevertheless, although the supply Department must seek to avoid duplicating the control which industry itself should exercise, we consider that some Government participation during full development is essential if the recommendations in the Handbook of Procedures are to be properly implemented. Where it has been possible to establish and define the tasks beforehand with sufficient precision to enable a fixed or maximum price contract to be placed,

participation in the tasks for which the contractor is responsible can be limited in the main to providing advice at the contractor's request and to establishing that satisfactory progress is being made. We think it unlikely, however, that it will be possible to place such contracts for the complex and technically advanced projects of the type that have caused the greatest concern in the past. Nor can we envisage a state of affairs on technically advanced projects where the advice of Ministry specialists, and frequent discussions between such specialists and contractors' staff, will not be required. We do not regard such discussions as interference, but rather as a pooling of knowledge and ideas on critical aspects of a complex task.

REFERENCES

1. CGWL Notice No. 198 and CA Notice No. Organization 35:
   'The object of a feasibility study is to establish whether it is practicable to meet a given requirement or Staff Target, to identify the scientific and technical problems involved in meeting it, to sketch the general outline of the approaches which are possible, to indicate which is preferred, and to indicate in broad terms the order of cost and time likely to be needed to complete the project on these lines.'
2. Appendix B to CGWL Notice No. 177 (Issue 3) and Appendix 2 to CA Instruction Chapter 104. The full reference is previously quoted in Note 2 to Chapter 7 of this report.
3. CGWL Notice No. 187 and CA Notice No. Organization 33.
4. A confidential Policy Estimate is defined as an estimate of cost which takes account of experience with other projects and which the supply Department considers it would be prudent to assume for purposes of a policy decision. Such an estimate must be treated as confidential.
5. A Confidential Policy Date is defined as the date at which the supply Department estimates, in the light of all the information available at the time, that deliveries of the first production equipment will be available for Service use. Such a date must be treated as confidential.
6. Report of the Committee of Enquiry into the Aircraft Industry—HMSO Cmnd. 2853, December, 1965.
7. Op. cit. paragraph 470.
8. Op. cit. paragraph 473.

CHAPTER 12

International Collaboration—The Effect of the Procedures Proposed

Introduction

285. We have not attempted in this chapter to deal with all the problems facing international projects. This would be outside our terms of reference. Nevertheless, we have felt it essential to give some consideration to certain existing procedural difficulties and to whether these would be increased or reduced by our proposed changes to United Kingdom procedures. Our main recommendation for the improvement of the post-Zuckerman stage-by-stage procedure is the introduction of a longer and more thorough Project Definition phase to replace the project study. We have also made it clear that we consider the need for such a phase to be greatest on the complex weapon system which draws together into an integrated whole a number of concurrent inter-related developments, some or all of which involve a significant technological advance. At the same time, it is on precisely this kind of project, with its high development cost and its short but expensive production run, that international collaboration seems most attractive. We therefore considered the effect of our proposals on our ability to harmonise our procedures with those of the United States and France, these being the two countries with whom collaboration seems most likely to occur in the coming years. We may also take part in joint ventures with other countries such as Canada, Germany, Holland, and Italy, but we have not sought to examine any special difficulties which might arise in these cases.

Effect of our proposals on collaboration with the United States

286. It will be apparent from our description in Chapter 8 of the American approach to the initiation of projects that the change we recommend will bring us closer to the American system. However, the definition we hope to achieve at the end of our proposed Project Definition phase, although an advance on that now obtained at the end of a project study, will still fall short of that sought by the United States before they go forward to Engineering or Operational Systems Development. The Americans also aim to keep competition going until that point and then to place an incentive contract, the strength of the incentive provision being dependent upon the nature of the development and the degree of technical advance. We envisage only one firm carrying out Project Definition, and we are doubtful whether the essential conditions we have outlined in Chapter 10 for an incentive contract will exist at that stage on the type of advanced project that we have in mind. Moreover, such competition as may take place in the United Kingdom before Project Definition is limited by the small number of companies from which proposals can be sought and the need to maintain a viable defence industry.

287. These differences serve to increase the difficulties of joint projects which require a willing partnership between British and American firms acceptable to both Governments. Not only will selection by true competition usually be impossible on the British side, but the chosen British firm may not be willing to co-operate with the American firm chosen by competition. This would conflict with established United States policy. Incentive contracting also becomes more difficult as there is no evident alternative source to which Governments can turn if necessary. In addition, there are liable to be difficulties over the allocation of production orders and in the most important collaborative projects so far undertaken, the United States Government has not been willing to agree to any predetermined ratios for these. This, again, appears to be due to the importance the Americans attach to price competition, as well as to their traditional, but now changing, attitude that defence equipment should wherever possible be purchased from sources within the United States.

288. When two countries take part in a joint project each must be prepared to adjust its own national procedures to fit in with those of the other. Unfortunately, room for manoeuvre appears limited because the American approach of maintaining competition and delaying a decision on the final phases of development until a late stage is impracticable for us on financial and industrial grounds. Moreover the United States dislike the British system of becoming committed to a particular firm at what they consider, and will probably still consider despite the longer exploratory phase we now propose, is too early a stage. This they believe is liable

to lead to the sort of difficulties, for example, slipping timescales and steeply rising costs, which they themselves have experienced and which their latest procedures are designed to avoid as far as possible. Nevertheless, some compromise will have to be found if joint UK/US development projects are to be undertaken on any scale.

289. However, although the difficulties are considerable, the procedures we have proposed in Chapter 11, together with the experience arising from the recent purchases by the United Kingdom of American aircraft, should help both to narrow the gap between the two countries on their approach to procurement, and to make British industry more receptive to the procedures with which they may be required to comply if successful UK/US collaboration is to be achieved. Although the purchase of Phantom aircraft cannot properly be regarded as a collaborative project, it will contain a substantial amount of British equipment. As a result, this aircraft, and to a lesser extent, the C.130 and F.111, has brought British firms into contact with American defence procurement procedures. The American insistence on fixed prices related to a detailed specification with financial penalties for late delivery, and with orders won only after competition with other companies, must be beneficial and should help to create a climate in which it should be easier to negotiate future collaborative arrangements as well as to make meaningful incentive contracts more possible on projects carried out in the United Kingdom alone. However, although our latest procedures may mitigate the problems by bringing our procedures closer to those of the United States, they will not remove the need for detailed negotiations and each case will have to be treated on its merits. Such negotiations take time and an allowance for this must be included in the programme.

Effect of our proposals on collaboration with France

290. Our main experience of collaboration with the French has been on aircraft, though there has been some experience in the guided weapon field. The French in common with the Americans and ourselves, dislike the cost reimbursement type contract for full development and it is their policy to contract step-by-step and to obtain fixed prices from the earliest possible moment. The French approach to aircraft development, as will have been apparent from Chapter 9, is to get a prototype into the air as soon as possible and their procedures allow them to take a decision to this end at a point even earlier than that equivalent to the end of our present type of project study. Their philosophy is, therefore, somewhat different from that of the United Kingdom and the United States, where first flight is only one of a succession of planned 'milestones' arrived at after careful study of all the tasks within the total development programme. In the United Kingdom, where advanced development has been mainly on a cost reimbursement basis, the successful flight of the first prototype has not normally had any special contractual significance. Nevertheless, experience with the Concord and Jaguar aircraft projects has shown that the French have taken some steps in recent years towards our stage-by-stage approach.

291. We find it hard to assess the effect of our main recommendation on our relations with the French, but it would appear that any move towards a longer and deeper exploratory phase such as we propose must underline rather than reconcile the existing difference of approach.

Further difficulties in international collaboration

292. There are two further groups of difficulties in international collaboration which need to be mentioned. The first group arises from the inevitable variations between the procedures of different Governments. For example, a typical Memorandum of Understanding provides for an equal division of work. This means that expenditure in one country has to be comparable with that of the other. However, there are many differences in detailed practices. Thus, in the United Kingdom, the main part of the profit margin is calculated by reference to the capital employed, whereas in France, it is a fixed percentage for each of the elements comprising the estimated or actual cost of production, including interest on borrowed money. In the United States, the Government provides defence contractors with a considerable amount of plant and machinery rent free, whereas the United Kingdom provides very little and also charges an economic rent. When such differences are multiplied many times over the various aspects of project administration, such as contract conditions, financial and budgetary

procedures, and methods of price fixing and cost control, it becomes a very difficult exercise to harmonize procedures to the extent necessary to satisfy each country that it is getting and paying for its rightful share of the work. This type of problem is unlikely to be affected by our proposals.

293. The second group of difficulties arises because in any contemplated international project, there are often pressures for early decision which entail the accepting of formal documents of commitment, usually termed Memoranda of Understanding between the two Governments, before much work has been done and almost certainly before a realistic programme and estimate can be prepared. Despite the formal termination provisions in most international documents, it becomes increasingly difficult as time passes for one Government to withdraw if the other wishes to continue; in practice, therefore, the United Kingdom has to be committed on international agreements at an earlier stage than if the project were to be undertaken wholly in this country. Moreover, a joint project means joint decision taking, certainly by Governments and probably by companies as well; the project thus tends to proliferate committees and to lack unified direction at both the industrial and the Government level and the delays in one country's administrative procedures can all too easily be added to those inherent in the other's. All these factors militate against incisive management although this is a vital constituent of the control procedures we have recommended.

Conclusions

294. Nevertheless, the need for improved procedures such as we have put forward is particularly great on international projects since, as we have seen, these tend to be of the type that experience has shown to be the most difficult to estimate and control. Our studies have shown clearly that over a wide range of projects, until Project Definition or its equivalent has been completed, it is impossible to define the likely technical content of a project, its programme, and its estimate, with sufficient precision to justify, in the normal course of events and on major technically advanced equipment, a commitment to full development. Nor it is possible to place meaningful fixed price or other incentive contracts until at least this stage. In these circumstances, we recommend that when consideration is being given to the possibility of undertaking a development project in collaboration with another country, the supply Department should aim to persuade our prospective partners to carry out Project Definition, or the work equivalent to it, before entering into any form of agreement which has the effect in practice of creating pressures which preclude our breaking off if further examination causes us to doubt the wisdom of pursuing the project to completion.

295. We recognize that in some cases it may not be possible to adopt the revised procedures we have recommended and that it may be necessary to compromise on some points. We consider, however, that all submissions which are prepared as a basis for a decision on whether to take part in a joint project should include a clear statement about the status of the development programme and cost estimate that is being put forward. In certain cases, and particularly when the supply Department has been unable to persuade the other country to carry out Project Definition first, this may be less firm than we should like to see achieved on a purely national project. When this occurs, it is important that it should be given explicit recognition at the time when the decision is made.

CHAPTER 13

Summary of Conclusions and Recommendations

Introduction

296. This chapter begins with a short narrative of our main conclusions and recommendations. This is necessarily very condensed, but it is followed by a full list which refers back to the paragraphs in earlier chapters where each point is covered in detail.

Conflicting factors in development cost estimating

297. The continuing pressure to contain defence expenditure within a target set some years in advance makes it more necessary than ever to be able to estimate future costs to within the narrowest practicable limits. Yet the operational and technical uncertainties associated with weapon and equipment development are usually too great to make close accuracy possible during the early stages of a project. The essence of our task has been to find the best compromise between these two conflicting factors.

Limitations of normal project study

298. Our investigations have shown that the type of project study that has hitherto been normal, consisting almost entirely of theoretical investigations with little or no experimental work, is unable to provide the comprehensive data about the equipment, its timescale, and its likely development and unit production cost, which is needed both for effective forward planning of defence expenditure and for the control of approved programmes. The stage of definition which can be obtained at this point is not sufficiently precise to enable more than a broad estimate to be prepared and this estimate is constructed in a way that makes it impossible to use it as an instrument of detailed budgetary control. We wish particularly to stress the latter point, which in the past has tended to be overshadowed by the attention given to the inadequacies of the estimates as such; unless an estimate is based objectively on the work to be done, and unless that work is broken down and phased into discrete tasks which can be used to check achievement, no direct basis exists for the control of out-turn against estimate.

299. These points apply with even greater force to project time and cost figures prepared at an earlier stage, for example, after a feasibility study or a brief preliminary survey. 'Programmes' and 'estimates' of this kind need to be treated with great caution and should be clearly described and recognized as giving only an indication of the project's likely order of magnitude.

Proposals for better project definition

300. If a more accurate estimate is needed on which to base a decision on full development, then the decision must be postponed until it is possible to resolve the major uncertainties of the project and to define in more detail what is to be developed and so to prepare a programme and estimate which sets out and costs the main elements of the work that will have to be undertaken to meet the Staff Requirement. How long this process of definition will take and how much it will cost will vary with the technical novelty and complexity of the project, but we believe up to two years and up to 15% of total development cost to be of the right order for a major project. By this time it should be possible to prepare a comprehensive provisional development specification and a realistic programme and estimate for developing and proving an equipment to that specification. This programme and 'synthetic' estimate will show the effort, time, and cost required to complete each of the major tasks into which the total development has been divided. It will include allowances for that work which cannot be objectively estimated. We would emphasize here that the essence of development is the testing of design. Realistic allowances based on relevant experience and judgment must be specifically made to cater for the rectification of what is found by testing to be wrong or inadequate in the initial design work, and for the subsequent retesting. The total estimate will thus include allowance for work which will inevitably be entailed, even if its detailed incidence cannot be foreseen; it will not include a contingency for the catastrophic failure.

301. This change to the procedures will not mean an end to rising estimates of development cost. We expect it to lead to a significant improvement, but the more a project reaches out into the technical unknown and the longer the proposed development timescale, the greater is the danger that for one reason or another the eventual cost will exceed the estimate at the time of first approval. The danger of under-estimation is greatest on the weapon system or equipment which requires the concurrent development and integration of a number of inter-related items embodying advanced and, particularly, unproven techniques. In these cases it is unwise to place too much reliance on estimates; the emphasis must be on control so that the earliest possible warning is obtained of cost trends. In the extreme case when for policy reasons it is desired to embark on development despite the acknowledged impracticability of achieving a soundly based estimate along the lines we propose, it is still important to insist on adequate project definition; otherwise there will be no worthwhile mechanism for 'controlling' outturn against estimate and thus no mechanism for throwing up comparative data for the necessary periodic reviews of the decision.

Consequent increase in scope for incentive contracting

302. Two of the products of the Project Definition phase we propose are a development specification and a synthetic estimate of cost. Since these are also the two most important pre-requisites for an incentive contract, the introduction of Project Definition will increase the scope for incentive contracting. The application of incentive contracting for development will tend to be restricted to areas of low technical risk.

Preparation and evaluation of development programmes and estimates

303. Before any estimate can be used as a basis for a Government decision, it must be prepared by a contractor and then evaluated by the supply Department. Our investigations convinced us that much needs to be done to improve the general standard of performance on both these two aspects. Recommended procedures to help industry with programming and estimating are included in the Handbook of Procedures at Appendix M. They are based on best current practice in British defence industry and we hope to see them widely adopted.

304. In the supply Department the nucleus of the project team must be formed before Project Definition begins and the team should be progressively strengthened thereafter. Greater continuity of staff is needed both on individual projects and in the field as a whole. The tours of Service officers in key posts should be lengthened and more attention should be paid to selecting staff with the necessary managerial qualities. Above all, there is an urgent need for an intensive training course in project management so that the staff concerned may become familiar with the best techniques now available. Such training should be based on a collated record of standard or approved procedure and practice. These measures should result in a more disciplined and professional approach to the task.

305. Many of the initial estimates prepared by contractors in the past have been grossly over-optimistic and the Ministry of Aviation has not always recognized this and made sufficient allowance for it. The Ministry cannot and should not try to match the expertise available in industry for the preparation of detailed programmes and estimates. Its function is to give guidance on certain important aspects, such as the coverage of the estimate, and then to assess the proposals it receives.

306. The staff of the Directorate of Technical Costs can contribute little to the assessment of estimates at the formative stages of a development project, although they can help on the manufacturing element as the project progresses and more drawings become available. The Directorate of Accountancy Services should be consulted on overhead rates and on the relationship between a contractor's Development Cost Plan and his cost allocation and cost collection system. It is not necessary for the professional accountant to be a member of the project team. His time would be better spent on a periodic review of each main contractor's system for the preparation of estimates and the authorization and recording of expenditure.

307. However, even if better-trained and more experienced staff were available in technical branches, this would not be enough to achieve the standard of assessment required. The Ministry's corporate experience must be brought to bear. Existing records do not permit this.

If better records could be prepared on what has been achieved on past projects and if these were collated and analysed, it should be possible in the formative stages of most new projects for the technical branches to prepare by parametric or comparative methods an independent estimate and to make a broad check on a contractor's estimate to ensure that it is of the right order. Although some analysis work of this kind is already being done in various parts of the Ministry of Aviation, it needs to be centralized and its coverage widened to take in all the most important technical areas. The units should cover production costs as well as development costs. This analysis work may be helped by information obtained in the future by the Department as a result of equality of information and post-costing.

308. The aim should be for the contractor and the supply Department at the end of the Project Definition phase to agree on a realistic estimate which would then be used as the basis for the Government's decision. Although it may be attractive for planning purposes for the supply Department to add a further margin as a precaution, this itself may well be contributory to rising costs and we believe that the problem would be better dealt with by having a central reserve for all projects. Allocations could then be made to particular projects if it became impossible to keep to the approved estimates. Although this change may not be feasible immediately, it should remain the objective. It would mean the eventual abolition of the present Confidential Policy Estimate procedure.

Need for timely decisions

309. In many cases decisions have not been reached during the three months following the completion of the project study, as the 1961 Report of the Committee on the Management and Control of Research and Development envisaged. As a result, projects have been delayed and their costs increased because the programme could not be carried forward at the most economic rate. If our proposals for a Project Definition phase are accepted, it will become even more important to reach decisions within the time allowed since by then expenditure and commitments will be increasing more rapidly. Most development programmes require a series of decisions and actions by a number of Government agencies as well as by the contractor and all must accept the discipline of working to the scheduled dates. Similarly during the Project Definition phase, the supply Department and the contractor's higher management must accept and ensure that the primary objective during that phase is to work towards the documentation upon which soundly based decisions can be taken—and not to anticipate these decisions by embarking prematurely on development work which can and should be deferred.

Estimating unit production costs

310. Since little purpose is served in developing an equipment that the customer cannot afford to buy in the quantity he really needs, more attention must be paid to estimating unit production cost during development. Wherever practicable a production cost aim should be included in a Staff Requirement. This will act as a restraint on the designer and should lead to greater attention being paid to possible trade-offs between performance and cost.

The approach to development in the United States and France

311. Differences in the industrial and financial environment make it im
United Kingdom to adopt the American 'building block' approach to de
scale. Nor are we able to make the same use of competition between contra
the scope for incentive contracting is more limited here. The French have an
us at present with their more compact Government organization and their n
system of administration, but their piecemeal approach to development is diffic
with our arrangements for long-term planning and forecasting.

Effect of our proposals on international projects

312. The adoption of Project Definition will narrow the procedural differer
selves and the Americans, but may widen it between ourselves and the I
international projects, we may not wish, or we may not be able, to persuad
undertake Project Definition as a first step and before any commitment
development. In such cases, we may have to commit ourselves earlier on full
we should normally aim to do on a purely national project. This involves an
should be recognized at the time.

List of Principal Conclusions and Recommendations

Staffing for project management

1. For all new projects the nucleus of the project team should be formed in time for it to take part in the discussions with the chosen contractor(s) on the content of the project study. It should be progressively strengthened thereafter so that it can make an effective contribution to the preparation and assessment of the Development Cost Plan on which the decision to proceed to full development will be based.

Chapter 5, paragraphs 35 and 36

2. Staff posted into branches engaged on project work should remain in post for longer periods (in particular, the length of the tours of duty of Service officers in key posts should be extended) and, where changes cannot be avoided, a reasonable period of overlap should be allowed.

Chapter 5, paragraph 37

3. A more disciplined and professional approach is required to project management. It must be regarded as an important function in its own right, having its own qualifications and expertise, and special training should be given to all officers concerned with it. In the selection of people for appointment to senior posts in 'project directorates', major weight must be given to their managerial ability and no one should be appointed unless he already has some experience in the field and has acquired some knowledge of the management techniques available.

Chapter 5, paragraphs 38–40 and Appendix H

4. Better guidance should be given to Ministry project officers on their responsibilities in the form of a concise, coherent and self-contained handbook. This should help to achieve a more common approach to project matters.

Chapter 5, paragraph 41

Evaluation of development programmes and estimates: the contributions of the Directorates of Technical Costs and Accountancy Services

5. Measures need to be taken to improve the Ministry's ability to carry out an effective evaluation of contractors' programmes and estimates of development costs, particularly those which form the basis for a decision on full development.

Chapter 5, paragraphs 42–45

6. The Directorate of Technical Costs has little to contribute to the evaluation of estimates at the formative stages of a development project. As the project progresses and more drawings become available, the Directorate can make an increasing contribution to checking estimates of development manufacturing cost and unit production cost.

Chapter 5, paragraphs 51–54

7. The Directorate of Accountancy Services is in the best position to advise on contractors' cost allocation systems, and also on overhead rates. Technical branches should be required to consult the Directorate regularly and as necessary on these aspects. If this is done, no significant extra benefit will be obtained from making the professional accountant a member of the project team.

Chapter 5, paragraphs 55–58

Need for project records and analysis

8. The Ministry's technical staff are not in a position to prepare detailed programmes and estimates: this task must be left to industry, although close Ministry supervision is essential. To enable them to make informed judgments on the validity of contractors' programmes and estimates, Ministry technical staff need to be able to bring past experience to bear. Proper records, carefully interpreted, are essential for this purpose.

Chapter 5, paragraphs 59–62

9. Although the need for systematically recorded information on past projects has been recognized for some time, much of the information required is not readily available, nor is it suitably recorded.

Chapter 5, paragraphs 63–64

10. Efforts to establish correlations between unit production cost and physical parameters of equipment should be encouraged. The conclusions we have reached on the need to be able to bring past experience to bear during the formative stages of development apply equally to production.

Chapter 5, paragraph 65

11. A drive is needed to record and collate the corporate experience of the Ministry of Aviation on project effort and cost. This will require a more systematic analysis of development programmes than has been achieved so far, and a larger and more professional organization than exists at present.

Chapter 5, paragraph 66

12. The formation of the Project Time and Cost Analysis Branch in the Controllerate of Aircraft is a first step towards improving the Ministry of Aviation's capability to apply the lessons of past experience systematically to the assessment of new development programmes and cost plans. As soon as the necessary specialist staff can be found, it should become part of a new, larger organization which would also cover aero-engines and some aircraft equipment, and production as well as development.

Chapter 5, paragraph 77

13. The majority of us recommend that a similar branch should be created in the Controllerate of Guided Weapons and Electronics, although some of us favour a single branch serving both the Controllerate of Aircraft and the Controllerate of Guided Weapons and Electronics.

Chapter 5, paragraph 77

14. It will be necessary to possess data for each of the main areas of a project. The information needed is similar to that required for effective monitoring and it should be collected primarily from the returns made by contractors for project management. These returns should be related to the development programme and cost plan so that achievement can be compared directly with plan.

Chapter 5, paragraphs 78–81 and Appendix I

15. Greater co-operation is required between technical, finance, and contract branches in the early stages of the project to ensure that the contract schedule, the development programme and cost plan, and the manhour, technical progress, and cost returns are all mutually consistent and so arranged as to assist the effective monitoring and control of the project.

Chapter 5, paragraph 83

16. Information obtained in the future by the Department as a result of equality of information and post costing may prove to be of considerable value in analysis work.

Chapter 5, paragraph 87

Overhead rates

17. The present practice of requiring contractors to use in their forward estimates the most recent overhead rates agreed with the Contracts Division, (or with the Directorate of Accountancy Services, subject to the final approval of the Contracts Division), is basically sound, provided contractors are also asked for their estimates of what the actual rates for the present year and future years will be.

Chapter 5, paragraph 88

18. Where a contractor prepares for his own purpose budget rates for Ministry work, he should use these in his cost plans for those periods up to and including the current year for which rates have not yet been provisionally or finally agreed with the supply Department.

He should also use the current year's budget rates for all future years, again with the qualification that he should be asked in addition to give separate estimates of the rates for future years if he expects these to be different from the current year's rates.

Chapter 5, paragraph 89

19. Technical branches should concern themselves with the efficiency of contractors' management, both overall and at departmental level, and should raise with the contractor and with the Directorate of Accountancy Services and the Directorate of Technical Costs any instances where inefficiency appears to be making overhead costs higher than they need be.

Chapter 5, paragraph 90

Checking financial control systems at contractors

20. Before any new major development contract is placed, the selected company's proposed system of control should be reviewed in order to be sure that the requirements of an effective system have been introduced. Where the supply Department is doing continuing major business with a contractor, his financial and accounting system should be checked at regular intervals, say, every five years.

Chapter 6, paragraph 97

Need for better project definition

21. In the great majority of projects investigated, the time and effort put into the project studies have been substantially less than that envisaged in the Zuckerman Report.

Chapter 7, paragraphs 135–136

22. On a number of projects firms have adopted what appears to have been a deliberately over-optimistic attitude in submitting estimates, making wholly inadequate allowances for the cost of overcoming the many problems that must be expected to arise during a development programme. The tendency for firms to under-estimate has been encouraged by the Ministry of Aviation's practice of inviting competitive design proposals. There also appears to be reluctance within the Ministry to add allowances of the magnitude that past experience might suggest is necessary.

Chapter 7, paragraphs 137–138

23. Although efforts to keep estimates down may be a necessary element in cost control, they must not be allowed to lead to the preparation of unrealistic programmes and estimates by contractors, still less to their acceptance by the supply Department.

Chapter 7, paragraph 138

24. There has been some improvement in the quality of estimates on which decisions to authorize developments have been based. Further improvements can be secured by the more detailed analysis of programmes into their constituent tasks. The definition thus achieved should provide a basis on which subsequent proposed changes to the programme can be assessed.

Chapter 7, paragraph 139

25. Even if the existing procedures were to be implemented more fully and studies were to be conducted to the depth envisaged in the Zuckerman Report, the estimates produced at the end of the project study stage would still be liable to fairly wide margins of error, particularly if the project involved areas of above average technical risk. Moreover, they could not be used effectively for a detailed comparison of actual out-turn with planned achievement. A much more detailed study of the development problems and the tasks to be undertaken is needed before a well founded programme can be established.

Chapter 7, paragraph 140

26. It is necessary to analyse the various methods of assessing the likely cost of development which hitherto have been collectively and indiscriminately termed 'estimates'. We can identify at least four methods, which we have called Subjective, Parametric, Comparative, and Synthetic.

Chapter 7, paragraphs 142–149

27. Whatever method of estimating is used, it is essential to make allowances for unforeseen difficulties which may arise at any stage and this can only be done by informed extrapolation from past experience based on analysed records of previous performance.

Chapter 7, paragraph 150

Estimating unit production costs

28. The importance of establishing probable unit production costs has not always been recognized. The combined cost of development and production should be considered from the outset and the correct balance achieved between factors such as size, weight, operating performance, and reliability on the one hand, and timescale and cost on the other. Wherever possible a unit production cost aim should be given to the contractor at some stage between the writing of the Staff Target and the end of the present type of project study, together with an estimate of the production quantities likely to be required.

Chapter 7, paragraphs 155–157

29. If this procedure is to be effective, the user Department must be able to establish a unit production cost estimate for the number of equipments it is planning to buy which is realistic in relation to the Staff Requirement: otherwise it will not be possible to make sensible 'trade-offs' between performance and cost should these become necessary.

Chapter 7, paragraph 158

Documents to be given to contractors

30. Subject to the normal safeguards for classified information, contractors should always be given the Staff Target or Staff Requirement on which their work is to be based.

Chapter 7, paragraph 161

31. The Headquarters Project Director should issue a management chart at the outset which clearly defines the responsibilities of the various Government agencies concerned with the project and the channels of communication between such agencies and the contractor.

Chapter 7, paragraphs 168–172

The approach to development in the United States and France

32. The American policy of not authorizing full development until the technology involved in the project has been demonstrated by comprehensive studies, and the manufacture and testing of experimental hardware, has much to commend it. However, we have not sufficient resources available to enable us to adopt this 'building block' approach over the whole field.

Chapter 8, paragraph 197

33. The French have a more compact inter-departmental organization and a more integrated system of administration.

Chapter 9, paragraph 208

34. The French approach to development is difficult to reconcile with our present system of long-term planning.

Chapter 9, paragraph 209

Incentive contracting

35. It has long been the Ministry of Aviation's policy to try to negotiate wherever possible a form of contract which provides the contractor with a financial incentive to keep his costs to the minimum compatible with the satisfactory performance of the work. The negotiation of incentives is dependent on the establishment of firm and realistic specifications and on the ability to make realistic estimates of cost and time based on those specifications. Advanced development work involves a degree of uncertainty which militates against this.

Chapter 10, paragraph 210

36. Having examined the pattern of incentive contracting for development work in this country and in the United States, we concluded that only in exceptional cases would the essential conditions exist for the successful negotiation of an incentive contract, and that we would not be able to follow the American 'building block' approach, nor their use of competition, to obtain incentive contracts.

Chapter 10, paragraphs 241–243

37. We support the present policy of seeking incentive arrangements for development work wherever possible. It would be too ambitious to try to introduce them generally: at this juncture it would be better to concentrate on improving techniques in the use of cost incentives and on gradually extending their application. Contractors should be required to make proposals for incentives as part of the Project Definition phase unless it is quite clear that the necessary preconditions for an incentive contract do not exist.

Chapter 10, paragraph 245

38. Incentive schemes will help to stimulate industry to produce better estimates at the earliest possible stage, particularly on projects of low risk. They will not help in the area where help is most needed, that is, the technically advanced system requiring the concurrent development of a number of major components and their integration into an effective whole.

Chapter 10, paragraph 246

Proposals for better project definition

39. The information and specifications which arise from the present type of project study are in general inadequate to provide a well-founded Development Cost Plan on which approval for full development can be sought. For this, greater depth of investigation is necessary and the present point of decision must be moved to the stage where the first well-founded 'synthetic' estimate of development cost and of unit production cost become available. This may involve expenditure of up to 15% of the estimated total development cost over up to two years.

Chapter 11, paragraphs 250–252

40. The present type of project study should be replaced by a new phase to be known as Project Definition. This would be in two stages, but would be covered by a single contract. It is of the essence that Project Definition should be a very searching investigation of the proposed project leading to the highest standard of definition possible at that point.

Chapter 11, paragraphs 253–254

41. The first stage of Project Definition (PD.1) would correspond broadly with the project study envisaged by the Zuckerman Report and would result in a first draft comprehensive Development Specification and a first Development Cost Plan containing estimates on a mainly comparative or parametric basis. The second stage (PD.2) would allow the contractor to refine and consolidate the data produced in PD.1: from PD.2 should emerge a Development Specification in precise terms and a Development Cost Plan, including an estimate of unit production cost, with estimates prepared on a mainly synthetic basis.

Chapter 11, paragraphs 257–258

42. The information emerging at the end of PD.2 should not only provide the basis for the estimate on which full development approval is sought, but a detailed programme against which progress can be monitored, and work and cost controlled.

Chapter 11, paragraph 259

43. A procedure on these lines would introduce a much needed element of flexibility into the present arrangements. It does not impose new development burdens on contractors. It aims to obtain through a more explicit and precise process of definition a better understanding of the nature and scope of the task ahead and its financial implications.

Chapter 11, paragraphs 261–262

44. For smaller projects, we propose a simplified procedure.

Chapter 11, paragraph 267 and Appendix M, Chapter 9

45. The contractor should be given a financial incentive to provide the documents at the end of each of the Project Definition stages in accordance with the agreed timetable, and the form of project organization and the methods of programming, budgeting, and recording technical and cost progress should be established before full development starts.

Chapter 11, paragraphs 268–269

46. The Handbook of Procedures at Appendix M which defines more fully the procedures we recommend is based on best current practice in the defence field. We look on this Handbook only as a starting point. It will have to be revised and improved as knowledge and experience grow, and machinery for this purpose may have to be created.

Chapter 11, paragraphs 271–272

47. Although additional outlay may be required in industry to bring procedures for programming, estimating, and controlling development projects up to the standard laid down in the Handbook of Procedures, we do not consider that this will more than marginally affect the cost of a major development project. Indeed, savings from the introduction of the new procedures may well more than offset the expenditure incurred.

Chapter 11, paragraph 273

Programme reserves and general contingencies

48. The procedure whereby the Managing Director of a company preparing a Development Cost Plan is invited to add his own general contingency should be abolished.

Chapter 11, paragraph 276

49. The use of Confidential Policy Estimates and Confidential Target Dates should also be abolished as soon as practicable. The estimate at the end of Project Definition, which will include all necessary allowances in the form of reserves of effort, time, and cost, relating to specific areas of work, should be regarded as final.

Chapter 11, paragraph 277

50. All staff responsible for estimating should be convinced of the need for estimates which are fully realistic and reasonable, and it must be made evident to all concerned that the determination to achieve such estimates exists at the highest levels and that there is nothing to be gained in the long run from over-optimistic assumptions.

Chapter 11, paragraph 278

51. There is likely to be a need for some years to come for the supply Department to make its own confidential assessment of probable time and cost. The long-term objectives should be to abolish general contingencies for individual projects and to have a single line entry for the whole field of project development.

Chapter 11, paragraph 279

52. Submissions to the Research and Development Board and the Weapons Development Committee should give the supply Department's own assessment of the realism of the contractor's proposals and should confirm that the studies have been carried out in sufficient depth and appear soundly based. If it is considered that particular areas have been insufficiently studied, the areas should be identified and the possible repercussions on the programme described.

Chapter 11, paragraph 280

Relations with industry

53. All Departments (including the Treasury) must accept in parallel with industry the disciplines and constraints entailed by the preparation of a plan at an early stage to which Government and industry will be expected to work. This plan should cover key administrative events as well as key technical events.

Chapter 11, paragraph 281

54. The proposals we have put forward are not inconsistent with what the Plowden Committee would like to see achieved in the area of financial and technical control. Very close liaison should be maintained during Project Definition. Once a programme has been firmly established, the need for continuous oversight should be reduced.

Chapter 11, paragraph 283

Effect of our proposals on international collaboration

55. Our proposed changes to the procedures will narrow the gap between U.K. and American development procedures, but may increase the differences between ourselves and the French.

Chapter 12, paragraphs 286–291

56. One of the difficulties of international collaboration is that there are pressures to enter into a formal international agreement before a realistic programme and estimate can be prepared. Moreover, as time passes, it becomes increasingly difficult, despite any formal termination provisions, for one Government to withdraw if the other wishes to continue. In these circumstances, the supply Department should always aim to persuade our prospective partners to carry out project definition, or the work equivalent to it, before entering into any agreement which commits us to pursue the project to completion. Where this is impossible, this should be given explicit recognition at the time when the decision is made.

Chapter 12, paragraphs 293–295

W. G. DOWNEY (*Chairman*)
L. R. BEESLY
J. B. L. CLARK
B. G. DICKINS
E. W. G. HAYNES
P. D. HENDERSON
E. S. JACKSON
H. L. LAWRENCE-WILSON
D. E. MORRIS
R. E. SAINSBURY
W. P. SHOVELTON
L. H. C. STERNE

A. C. GREGORY } *Liaison Officers*
J. B. VISSER }
T. F. KNAPP (*Secretary*)

List of Appendices

Appendix	*Chapter Reference*	*Subject*	*Page*
A	1	Terms of reference of the Steering Group	80
B	2	‘Financial Management’, Permanent Secretary’s directive of March, 1960	81
C	2	‘Financial Management of Research and Development’, Permanent Secretary’s directive of April, 1960	83
D	4	Case studies carried out in industry: Terms of reference of the management consultants	85
E*	4		
F*	4		
G	5	Project management: Changes in key Ministry of Aviation personnel	88
H	5	Project Management Training Course: Illustrative syllabus	90
I	5	Development programme analysis: Data required	92
J	6	Auditors’ reports on financial control systems: List of companies reviewed	94
K	6	Case studies carried out in industry: Summary of Agreed Statements of Fact	95
L	7	The control of research and development: Principal CA and CGWL instructions	110
M	11	Programming, Estimating, and Control of Development Projects: Handbook of Procedures	111
N	11	Handbook of Procedures: Supporting action by the supply Department	112

* These Appendices, which list certain projects and contractors, are omitted from this published version of the Report to protect commercially-confidential information.

APPENDIX A

(Reference: Chapter 1)

Terms of Reference of the Steering Group

1. To examine and consider the methods used in industry for estimating the cost of developing and producing defence equipment (other than atomic weapons) in accordance with stated requirements and in the Department for checking such estimates; to examine and consider the methods used by both parties for the subsequent control of development and estimated production cost against approved estimates and against technical progress; and to make recommendations.

2. To consider case histories and current procedures, and to collect evidence from within the Department and from industry.

3. To make enquiries into the methods adopted in this context in certain other major industrial countries.

4. As considered necessary, to appoint sub-groups from its own membership or otherwise and to receive reports therefrom.

5. Without limitation on the generality of Item 1, to consider and make recommendations on:

   (a) Departmental requirements on contractors as to the format, content, and methods of compiling development cost estimates and associated documents;

   (b) industrial methods of planning and estimating the cost of development and production work and of the subsequent technical and financial control of development, with particular emphasis on the inter-relations between technical progress and financial expenditure and of the effect of development on production cost;

   (c) Departmental procedures and methods for the scrutiny and handling of contractors' development and production cost estimates;

   (d) industrial and Departmental procedures for the detailed scrutiny of design, development, and production proposals to ensure all possible economy;

   (e) specific, general, and block contingency allowances; and

   (f) procedures and channels of communication between the Department and the contractor and within the Department during the course of development with particular reference to responsibility for—

      (i) new design requirements and design changes affecting cost, and

      (ii) reporting estimate variations.

6. To report to the Permanent Secretary.

APPENDIX B

(Reference: Chapter 2)

Financial Management

1. We have recently discussed and, subject to some minor amendments, endorsed the findings of the first four study groups on aspects of the financial management of research and development. The terms of reference of the groups and summaries of their accepted recommendations are in Papers RDB/P(60)4 and RDB/P(59)91 of the Research and Development Board.

2. With the acceptance of these reports we are deliberately changing the emphasis in the management of the research and development programme. We shall put all the necessary detail into formal shape as soon as possible, but meanwhile I should like to set out quite briefly what our general aims are and how we mean to achieve them. I am sure you will agree that these points need to be quickly and widely appreciated throughout the Department. Many of them are applicable not only to research and development but to the whole of our work.

3. It is our duty to secure the maximum value for the money spent under our direction. Cost control must, therefore, be accorded equal importance with technical control. What is mainly needed is to bring technical and secretariat branches closer together and ensure that both take not only a close interest in getting value for money but a share in the responsibility for it.

4. It is clearly unbusiness-like to enter into undefined and unlimited commitments. Therefore the Department should not embark on developments or accept requirements from the Service Departments or others, until it knows both the nature and the cost of the work involved. Nor must the Department issue a contract which does not delimit the work to be done.

5. This will not delay, but hasten, the satisfactory completion of the job. If work is to be done efficiently, it must be well planned; and it is better that the planning should be done before the Department enters into any large scale commitment than afterwards. If the whole scope of a project cannot be defined at the outset, then some more limited objective must be set; for example, the preparation of a design study or the commissioning of a definite amount of work which will carry the definition of the main project a stage further and aim at the provision of both a specification and a sound estimate of cost. Special care must be taken to avoid committing the Department in advance of a formal contract document.

6. The Department's contractors should also be encouraged to assume a greater sense of financial responsibility. Contractors who make proposals for a development project should submit a detailed costed programme over the signature of a person authorized to commit the company; that is to say a director, manager, or secretary of the company. No contract for full development as distinct from a contract for a design study or a contract for a limited period of development, should be issued to a company which has not provided such a programme. If the outcome shows the programme to have been at fault, this must be brought home to the management of the Company by a senior officer of the Department. Any important cases, in which a contractor's management appears to have been bad, should be reported to me so that I may consider whether to intervene personally. Such cases might well be considered by the Research and Development Board.

7. We should, wherever possible, lay on contractors a financial liability for the accuracy of their project estimating and the efficient management of projects. It is the Department's policy to negotiate, wherever possible, a form of contract which provides the contractor with such a financial incentive. For research and development there is often no alternative to a contract at cost plus profit; but even in those cases it may be possible to establish an incentive, for example, by limiting the profit which the contractor can earn. It is the task primarily of the Contracts Division to negotiate the contract terms appropriate to each particular case; but other branches must give the Contracts Division every assistance. All of us who have contact with industry must make it clear that it is the Department's policy to use incentive contracts wherever possible, and must take care in preliminary discussion not to prejudice the Department's negotiating position in this or in any other respect.

8. There is one situation where prompt and decisive action is of particular importance. The Department uses the 'Limitation of liability' clause to require contractors to give notice when a predetermined level of commitments is reached. When this notice reaches the Department, the contractor must be told quickly and clearly whether he is to continue work under the contract and, if so, the new limit of liability that is to operate. Dilatoriness can easily destroy the Department's ability to limit its expenditure.

9. We are making changes in our procedures which should help to improve our efficiency, and there may be more to be done in the same direction in future. But although good organization and procedures are a necessary condition of good management they are not by themselves sufficient. In the last resort management depends on people and how they get on together. In particular there must be the fullest exchange of information between technical, finance, and contracts branches if all are to do their jobs properly. Success or failure depends on the efforts of the whole of the team.

21st March, 1960

W. STRATH

APPENDIX C

(Reference: Chapter 2)

Financial Management of Research and Development

1. In my minute of 21st March I set out some of the changes in emphasis which resulted from the acceptance of the reports of the first four study groups on aspects of financial management of research and development. The purpose of this minute is to set out the respective responsibilities of technical, administrative, and contracts branches for financial management and to emphasise the need for the closest co-operation between them.

2. Technical, administrative, and contracts branches must form a team and work in harmony, and each branch must understand clearly what are its own responsibilities and what the responsibilities of others. If this is not done, the team which should be an instrument of dynamic management can quickly degenerate into the worst form of administration by committee. My purpose in this minute is to define where these different responsibilities should lie.

3. It is the responsibility of the technical branches to assess the implication in terms of effort, time, and money of requirements placed on the Department and to prepare estimates of the extramural cost of projects both in total and year by year. Technical branches must satisfy themselves that the proposed programme of development is not only the best technical method but also the most economical method of achieving the objective. In preparing these estimates they will require assistance from the administrative and the contracts branches; for example, any information which the Department has on the actual cost of similar work or on the cost of other work done by the contractor being considered for the job, will be of value to the technical branch in making their project estimate, and must be available to them.

4. It is the responsibility for the administrative branch to satisfy itself that the estimate put forward by the technical branch is a valid one; that is, that the assessment has been properly carried out and that due allowance has been made in the estimate for technical uncertainties. The discharge of this responsibility is facilitated by close co-operation between branches in the preparation of estimates. The administrative branch also has the responsibility for estimating the charges to the Department's Vote year by year if the project proceeds. The difference between the cost of the work done and the payments made is not dependent on technical factors; the administrative branch is best placed to make the necessary assessment of the Department's cash expenditure.

5. The administrative branch alone is empowered to authorize the incurring of financial commitments on behalf of the Department. Before giving financial approval, the administrative branch must satisfy itself that the most economical method of achieving the objective has been chosen, that the work is in accordance with currently accepted policy and that the approval of the Research and Development Board, the Defence Research Policy Committee, the Minister, and the Treasury has been obtained where necessary; that adequate financial provision has been made or is likely to be available in the Department's Estimates; and that the cost of the work is a proper charge on the Department's Vote. If there has been proper collaboration between the technical branch and the administrative and contracts branches before the project is submitted for financial approval, the administrative branch should already be in possession of the information it requires for its decision. The estimate, as thus finally approved after full consultation at all stages between the technical and administrative branches, binds both alike and determines their future actions.

6. The contracts branches alone are authorized to place contracts for the Department. I have emphasized in my earlier minute the importance of avoiding any irregular commitment, and of having fixed price contracts or contracts which give the contractor an incentive towards efficiency wherever possible. The contracts branches need the active co-operation of the technical and administrative branches if they are to get the best possible terms of contract in every case.

7. When a contract has been placed, the technical branch is responsible for the efficient management of the project, that is for seeing that it is carried forward in accordance with the agreed programme, as regards the technical progress of the work, the timescale and the expenditure authorized in total and year by year.

8. The administrative branch has the duty of ensuring that the Department's expenditure is within the total granted by Parliament. It will accordingly inform the technical branch if considerations of Parliamentary Vote accounting require special action to adjust the rate of spend.

9. While then the technical branches are responsible for project management in the widest sense, the staff in these branches must constantly remember the limitations which stem from the responsibilities which belong to the administrative and contracts branches:

(a) they must not, without the prior approval of the administrative branch, allow commitments to be incurred which would lead to expenditure eventually exceeding that approved. If a proposed change in the programme or in the requirement seems likely to cause the annual or the total cost of the work to exceed that authority, the project must be reconsidered and a fresh approval sought; and

(b) they must not commit the Department before a contract has been placed by the Contracts Division nor encourage contractors, explicitly or implicitly, to do work or incur expenditure in excess of that provided for in the contract.

10. The need is for a proper understanding of the duties and responsibilities of branches and the greatest possible flow of information between them. For some of the largest projects, management teams are being set up; for the smaller projects an equally close association is desirable and can, I am sure, be obtained without formal organization.

8th April, 1960 W. STRATH

APPENDIX D

(Reference: Chapter 4)

Case Studies Carried out in Industry: Terms of Reference of the Management Consultants

1. To prepare a case history of the steps taken by (names of firms) in preparing for the Ministry of Aviation the successive Development Cost Plans and estimates of unit production cost for the (names of project) and of the methods used by these contractors for the control of development against approved estimates and for the review of development and unit production cost in the light of technical progress.

2. Without limitation on the generality of Item 1, to report on the following points:

   (a) the adequacy of the definition of the Ministry's requirement;

   (b) the instructions or guidance issued to the contractors by the Ministry for the preparation of technical programmes of work and their associated cost plans to meet the Ministry's stated requirement;

   (c) the methods used by each contractor to prepare—

      (i) his proposed programme of development work including the tests proposed;

      (ii) his estimates of the manpower, time, and, where relevant, materials and bought-out equipment, needed to carry out this programme;

      (iii) the translation of these estimates into money terms including overhead and profit additions; and

      (iv) the estimates of production cost made during the development stage;

   (d) the adequacy of the design specification prepared at the end of the project study;

   (e) the records maintained by each firm linking technical characteristics or performance with development or unit production cost and their suitability for use in preparing or checking the estimates for new development projects;

   (f) the methods used by each contractor to control work, expenditure, and commitments in accordance with the approved technical programme and cost plan and to ensure that each step in the technical programme is fully achieved;

   (g) the reports received by the senior management in each firm on technical progress and on financial expenditure and commitments and the arrangements for correlating the one with the other and for assessing the financial effects of technical delays;

   (h) the arrangements in each firm for the regular review of the content and phasing of each step in the technical programme and of the associated development and unit production cost estimates and the reporting to the Ministry of any changes recommended;

   (i) the use made by each firm before production begins of the techniques of value engineering;

   (j) the procedures in each firm for dealing with the new design requirements or design changes affecting cost including the arrangements for ensuring that the unit production cost consequences of such new requirements or changes are taken into account;

   (k) as far as possible the extent to which the difference between the original estimate and the latest estimate is due to—

      (i) changes in or additions to the Ministry's requirement;

      (ii) lack of definition of the requirement;

(iii) changes in the method of meeting the requirement;

(iv) under-estimation of the cost of the method;

(v) changes in labour rates or material costs, overhead or profit rates;

(vi) an unexpected technical disaster (e.g. the loss of a prototype aircraft); or

(vii) such other breakdown as the team thinks shows most clearly the major reasons for the under-estimation; and

(l) the items in the cost plan provided at the end of the project study which, with the benefit of hindsight, are now seen to have been inadequately studied or defined.

APPENDICES E AND F

These Appendices, which list certain projects and contractors, are omitted from this published version of the Report to protect commercially-confidential information.

APPENDIX G

(Reference: Chapter 5)

Project Management: Changes in Key Ministry of Aviation Personnel

A: Table showing numbers of key personnel concerned with a selected group of major projects:

	Project	Duration as at June 1966	Key Technical Officers			Key Finance Branch Officers			Key Contracts Officers		
			Directors	Assistant Directors	Development/Engine Project Officers	Assistant Secretaries	Principals or Chief Executive Officers	Higher Executive Officers	Assistant Directors	Senior Executive Officers	
	Bombers										
1	TSR2 (see Note 1)	7½ yrs	2	1	1	3*	5*	2	3	2	1
2	Victor B2	10 yrs	5*	5	3	3	4	5	4	4*	2
3	Vulcan B2	10½ yrs	5*	5	2	3	5	5	4	3	3
	Fighters										
4	Buccaneer S2	5¼ yrs	3	4	2	4*	5*	3	3	2*	4
5	Lightning Mark 3	9 yrs	3*	3	4†	2	4	5	5*	3	5
	Transport Aircraft										
6	Belfast (See Note 2)	6½ yrs	3	2	4†	4	5	2	4***	4*	6
	Engines										
7	BS 100 (See Note 3)	4 yrs	3*	3**	2	2	1	2	2	1	7
8	BS 1003	6 yrs	4**	3*	3	2	5	4	3*	4	8
9	Olympus 22 R (See Note 1)	7½ yrs	3	1	2	3*	7*	4*	2	4**	9
	Aircraft Equipment										
10	Automatic Flight Control System	7½ yrs	2	2†	1	3*	3	3	3*	3	10
11	Forward Looking Radar for TSR2	4¼ yrs	1	2	2	2	4	2	2*	2	11
	Guided Weapons										
12	Bloodhound Mark 2	8 yrs	4	5	4	4	5	3	4**	7*	12
13	Sea Dart	7 yrs	3	3†	3	4	4	3	3**	1	13
14	Thunderbird Mark 2	10¼ yrs	4	2	4	5	6	4	4**	4*	14
	Electronics										
15	A Large Ground Radar	8 yrs	4	3	2	3	4	3	3	3	15
	Nuclear Weapons										
16	A Nuclear Weapon (See Note 4)	5 yrs	1	1	1	2 —	2 2	1 2	3	2	16
	Average length per project	7¼ yrs									

B: Table showing average number of key officers per project:	3·1	2·8	2·3	3·1	4·4	3·3	3·3	3·1
C: Table showing average tenure of each key post in years:	2·3	2·6	2·9	1·7	1·6	2·2	2·2	1·7

Symbols	*Explanation*
*	Indicates that a change in personnel resulted from the transfer of responsibility to another branch.
†	Indicates that a change in personnel resulted from the promotion of an officer who continued with the project in his higher grade.

Notes

1. This project was cancelled in April, 1965. A three-months run-down period was allowed. Since then, both the Assistant Secretary and the Principal of the administrative branch dealing with the residual work have changed. These changes have *not* been included in the table.

2. There have been two Development Project Officers for this project throughout. One Development Project Officer post has been filled by three officers in succession. The other post has been held continuously by the same officer.

3. This project was cancelled in February, 1965. A three-months run-down period was allowed. Since then, the Principal of the administrative branch dealing with the residual work has changed. This change has *not* been included in the table.

4. Until November, 1962, the finance of this project was managed by the normal administrative branch arrangement (Assistant Secretary; Principal; Higher Executive Officer). In November, 1962, the administrative branch was made the charge of a Principal (working direct to an Under-Secretary) assisted by Senior Executive Officers and Higher Executive Officers. There have been two holders of the Senior Executive Officer post (not included in the table).

5. On six projects, one or two of the key posts shown were vacant at some point for a period of four weeks or more. The project most affected was the Belfast Transport Aircraft on which three such vacancies occurred in the technical field, two for the post of Director and one for the post of Assistant Director.

APPENDIX H

(Reference: Chapter 5)

Project Management Training Course: Illustrative Syllabus

Day	9.15 am to 10.45 am	11.15 am to 12.45 pm	2.15 pm to 3.45 pm	4.15 pm to 5.45 pm	8.15 pm to 9.45 pm
1 Monday		11.30 am *Start of Phase 1* 1 Welcome; Opening Address; Self-Introduction of Students	Lecture— 2 Ministry Procedures for Research and Development Projects	Lecture— 3 Human Relations in Project Management	Visiting Speaker— 4 The Ministry's Project Management Team
2 Tuesday	Lecture— 5 Results of Previous Practice—Need for Improvement	*Start of Phase 2* 6 Lecture— Broad Introduction to Handbook of Procedures	Lecture— 7 Project Definition	Discussion— 8 Project Definition; Briefing and start of Case Study on Project Definition	Visiting Speaker— 9 Problems of Project Definition
3 Wednesday	Syndicates— 10 Case Study on Project Definition	Syndicates— 11 Report on Case Study on Project Definition	Lecture— 12 Development Programming (Part 1)	Film— 13 by Costain—'Critical Path'; Programmed Instruction—Network Analysis	Visiting Speaker— 14 Problems of PERT in Practice
4 Thursday	Programmed 15 Instruction continues—Network Analysis	Lecture— 16 Development Programming (Part 2): includes resource allocation and refinement of programmes	Discussion— 17 Resource Allocation: Briefing and start of Case Study on Development Programming	Syndicates— 18 Case Study on Development Programming	Visiting Speaker— 19 Programming Research and Development Work of High Novelty
5 Friday	Syndicates— 20 Report on Case Study on Development Programming	Film— 21 by U.S. Navy—'Breakthrough'	Lecture— 22 Development Cost Estimating	Discussion— 23 Development Cost Estimating; Briefing and start of Case Study on Development Cost Estimating	Visiting Speaker— 24 Problems of Estimating Research and Development Costs
6 Saturday	Syndicates— 25 Case Study on Development Cost Estimating	Syndicates— 26 Report on Case Study on Development Cost Estimating	Free	Free	Free

Day	9.15 am to 10.45 am	11.15 am to 12.45 pm	2.15 pm to 3.45 pm	4.15 pm to 5.45 pm	8.15 pm to 9.45 pm
7 Sunday					Film— 27 by I.C.T.—'The Future came Yesterday': the use of computers for business planning and control
8 Monday	Lecture— 28 and discussion— The Appraisal of Development Cost Plans	Visiting Speaker— 29 Cost Effectiveness and Marginal Trade Offs in Defence	Film— 30 by B.P.C.— 'Value Analysis': applications to engineering design	Lecture— 31 Monitoring Technical Progress	Visiting Speaker— 32 Progress Reports for Research and Development Management.
9 Tuesday	Film— 33 by I.C.T.— '1900 Series PERT'	Syndicates— 34 Case Study on Monitoring Technical Progress	Syndicates— 35 Report on Case Study on Monitoring Technical Progress	Programmed Instruction— 36 (1) Elements of Cost Accounting (2) How to Read a Balance Sheet (Parts I to III)	Visiting Speaker— 37 Development Contracts and Project Control
10 Wednesday	Lecture— 38 Monitoring of Cost Progress	Syndicates— 39 Case Study on Monitoring Cost Progress	Syndicates— 40 Report on Monitoring Cost Progress Case Study	Film— 41 by Management Services Corpn.—'PERT/COST'	Visiting Speaker— 42 Comparison of Technical and Cost Reports from Contractors
11 Thursday	Lecture— 43 Unit Production Cost Estimating	Worked Examples— 44 Planning the Transition from Research and Development to Production	Visiting Speaker— 45 Recording and Analysis of Programme and Cost Data	Visiting Panel— 46 Brains Trust on Project Management	Visiting Panel— 47 Brains Trust continues
12 Friday	Visiting Speaker— 48 (9.00 am to 10.00 am) Anglo-French Project Management Problems	Visiting Speaker— 49 (10.30 am to 11.30 am) Franco-English Project Management Problems	11.30 am—Summing up		

October, 1966.

APPENDIX I

(Reference: Chapter 5)

Development Programme Analysis: Data Required

This Appendix tabulates the information on development programmes which a pilot investigation suggests is required for an analysis of the inter-relation of costs, time-scales, and technical characteristics in the airframe field. Table A shows the separate specialist areas for which information should be recorded; Table B shows the type of information which should be recorded in each of these areas; and Table C shows the kind of major event which should be included in project diaries.

A: Table showing typical specialist areas for which information is required

Airframe complete
Fuselage
Wing
Empennage
Alighting gear
Fuel system
Electrical system
Hydraulic system
Pneumatic system
Oxygen system
De-icing system
Fire protection system
Cabin conditioning system
Control system
Engine installations
Navigation (and attack) systems installations
Radio installations
Armament installations
Emergency equipment
Furnishing and interior fitments
Ground support equipment (a) Development
(b) Service
Mock-ups
Wind tunnel models
Structural and other test specimens
Computers
Weight analysis
Jigs and tooling
Instrumentation and its installation
Trials support
Publications
Spares
Refurbishing of aircraft and equipment

B: Table showing type of information to be recorded in specialist areas

For comparative and synthetic estimates

1. Periodic returns relating to prototype and/or development batch aircraft under the following headings, where appropriate, for the airframe as a whole, and for its components, systems, and specialist areas, as shown in Table A. Where sub-contractors are involved, these should be indicated.

   (a) Manhours for design and development (development testing to be shown separately where feasible);

   (b) manhours for manufacture (quantities of airframes, equipments, or items to be shown);

   (c) manhours for assembly of major components and systems, and check testing;

   (d) the cost of (i) materials; and
   (ii) bought-out finished items;

(e) the direct labour employed on (i) design and development;
(ii) manufacture; and
(iii) assembly and check testing;

(f) the time taken to complete design and development of the items listed and their relative phasing;

(g) the numbers of drawings issued against each of the items at successive periods throughout the project; and

(h) a copy of the Directorate of Accountancy Services cost allocation sheet for the factories in which the work was done.

2. Flying hours and number of sorties for each aircraft per month, both at firms and Establishments, and a description of the tasks on which they were engaged.

3. The development programmes issued throughout the project, together with the associated cost plans so that achievement as determined by 1 and 2 above can be directly compared with the plans at different stages. This information must be supplemented by copies of the requirement and the specification, together with their amendments; also by project diaries recording significant achievements and setbacks, along with the reasons for them; major policy decisions; technical and financial decisions; and associated file references.

For parametric estimates

In addition to the information required for comparative and synthetic estimates, aircraft and engine design parameters and performance data are also required, together with the information on the weight and density of the aircraft as a whole, and the weights of the major systems and elements.

C: Table showing kind of major event to be included in project diaries

Feasibility study	—	Date of contract Date of submission to supply Department
Project study	—	Date of contract Date of submission to supply Department
Advisory Design Conference		
Approval of specification (and subsequent major amendments)		
Development contract	—	Date of contract
Mock-up conferences		
Production contract	—	Date of contract
First Modification Meeting		
First flight of prototype aircraft		
First flights of development batch aircraft		
Commencement of flight clearance tests at the Aeroplane and Armament Experimental Establishment		
First flight of first production aircraft		
Final Conference		
Initial release by the Controller of Aircraft (to defined standard)		
Delivery of first aircraft to Services		
Full release by the Controller of Aircraft (to defined standard)		

APPENDIX J

(Reference: Chapter 6)

Auditors' Reports on Financial Control Systems: List of Companies Reviewed

A: Airframe, Aero-engine, and Helicopter Companies (including guided weapons activities)

British Aircraft Corporation

1. Bristol Aircraft Ltd.—now divided between Filton Division and Guided Weapons Division
2. English Electric Aviation Ltd.—now divided between Preston Division and Guided Weapons Division
3. English Electric Co. Ltd., Aircraft Division—now part of Preston Division
4. Hunting Aircraft Ltd.—now Luton Division
5. Vickers-Armstrongs (Aircraft) Ltd.—now Weybridge Division

Hawker-Siddeley Aviation

6. A. V. Roe & Co. Ltd.—now H.S.A., Manchester
7. Blackburn Aircraft Ltd.—now H.S.A., Brough
8. Folland Aircraft Ltd.—now H.S.A., Hamble
9. The de Havilland Aircraft Co. Ltd.—now H.S.A., Hatfield
10. Hawker Aircraft Ltd.—now H.S.A., Kingston
11. Whitworth Gloster Aircraft Ltd.—now H.S.A., Bitteswell

12. Handley Page Ltd.
13. Short Bros. & Harland Ltd.
14. Bristol-Siddeley Engines Ltd.
15. Rolls-Royce Ltd.
16. Westland Aircraft Ltd.

B: Aircraft Equipment, Electrical, and Electronic Companies (including guided weapons activities)

17. Associated Electrical Industries Ltd.
18. Automatic Telephone & Electric Co. Ltd.
19. Bristol Aerojet Ltd.
20. Cossor Radar & Electronics Ltd.
21. Decca Radar Ltd.
22. Dowty Fuel Systems Ltd.
23. E.M.I. Electronics Ltd.
24. Elliott Bros. (London) Ltd.
25. Ferranti Ltd.
26. Flight Refuelling Ltd.
27. Hawker Siddeley Dynamics Ltd. (involving parts of A.V. Roe & Co. Ltd., the de Havilland Aircraft Co. Ltd., and Whitworth Gloster Aircraft Ltd.)
28. Hunting Engineering Ltd.
29. Lucas Gas Turbine Equipment Ltd.
30. Marconi's Wireless Telegraph Co. Ltd.
31. M.L. Aviation Co. Ltd.
32. Mullard Group (comprising Mullard Ltd. and Mullard Equipment Ltd.—the latter now M.E.L. Equipment Co. Ltd.)
33. Plessey U.K. Ltd.
34. Smith's Industries Ltd. (formerly S. Smith & Sons (England) Ltd. Aviation Division)
35. Sperry Gyroscope Co. Ltd.
36. Standard Telephones & Cables Ltd.
37. Ultra Electronics Ltd.

APPENDIX K

(Reference: Chapter 6)

Industrial Case Studies: Summary of Agreed Statements of Fact

1. **Introduction**
2. **Project Definition**
3. **Development Programming**
4. **Development Cost Estimating**
5. **Monitoring and Controlling Technical Progress**
6. **Monitoring and Controlling Cost Progress**
7. **Unit Production Cost Estimating**
8. **Records Linking Performance or Technical Characteristics with Cost**
9. **Value Engineering**
10. **Design Changes**
11. **Reasons for Changes in Estimates**
12. **Contractual Aspects**

1. Introduction

At the request of the Steering Group on Development Cost Estimating twelve investigations in industry were carried out between May 1965 and March 1966 by two firms of management consultants:

Associated Industrial Consultants Limited

P.A. Management Consultants Limited

The purpose of these investigations was to enable the consultants to report to the Steering Group on the methods used by some of the major contractors to the Ministry of Aviation for preparing technical programmes of development work, estimating the cost of such programmes, and for controlling work in accordance with the approved technical programmes and cost plans.

The terms of reference given to the consultants are reproduced in Appendix D of the Steering Group's Final Report.

Separate reports were prepared and presented to the Steering Group at the conclusion of each investigation. Each report contained three main parts:

Statement of fact agreed by the contractor

Consultants' comments and conclusions

Contractor's comments.

The purpose of this Report is to summarize the main items of significance in the Statements of Fact in these individual reports.

The consultants would like to record their appreciation of the courtesy and willing co-operation extended to them by the managements of the contractors visited, without which these studies could not have been made.

The consultants would also like to thank the many officers of the Ministry of Aviation who have given valuable assistance, and in particular the Ministry's liaison officers for their unfailing guidance throughout the whole of the investigation.

2. Project Definition

2.1 Adequacy of definition of Ministry requirement

In two of the twelve projects investigated no specific requirement was issued to the contractor. In one of these two cases no formal contractual agreement was reached until a late stage when most of the work had been completed: in the other, definition emerged as a result of studies undertaken by the contractor over an extended period. Of the remaining ten projects, seven contractors considered the definition of the requirement adequate with certain reservations, whilst in three cases the definition was thought unsatisfactory.

Two of the instances where contractors considered the definition of the requirement unsatisfactory were concerned with the same weapon system. The problems were caused by the fact that it took almost two years to reach a firm requirement on which development could proceed. During this period the requirement was substantially altered on four occasions with consequent invalidation of previous programmes and cost estimates. This prolonged uncertainty handicapped the project in three main ways:

(a) contractors were prevented from proceeding with full development as early as, or at the rate, they had envisaged. This caused postponements in the likely in-service date;

(b) a great deal of the work done by contractors during the two years of uncertainty was rendered abortive; and

(c) there was no consistent basis for programming and estimating.

In the third project in which definition was considered unsatisfactory the requirement was issued to five contractors as a basis for competitive project studies. The definition in this case allowed too wide an interpretation of the requirement, with the result that individual contractor's interpretations produced project study reports which were not strictly comparable. This led to difficulty and delay in the selection of a contractor to undertake development.

In one instance the definition of requirement given to the contractor, although adequate, was considered too detailed. On this project the contractor was Design Authority but the Feasibility Study was carried out by the Research and Development Authority who built a model which showed that the user's needs as reflected in the Staff Requirement could be met. The requirement was conveyed to the contractor in a specification which was virtually a description of this model and showed not only what the user required but also detailed means of achieving it. The contractor was uncertain of his design authority and wasted time and money persisting with features in the specification which his own work had shown to be inferior to some alternative method of meeting the user requirement.

One contractor felt that although the requirement was adequate in defining parameters of performance, the document was drafted in an un-professional manner and did not distinguish sharply enough between absolute necessities and aspects of performance which were only very desirable.

A feature incorporated into one requirement for an electronic equipment and found particularly helpful by the contractor was a statement of design priorities, i.e.:

1. Maximum range
2. Maximum reliability
3. Ease of operation
4. Minimum size and weight
5. Minimum power consumption
6. Ease of maintenance.

2.2 Adequacy of the design specification prepared at the end of the project study

Ten of the projects investigated went through the stage of a design or project study and in all but two of these a design specification was issued at the end of the study.

In one of these two the design study contract covered the investigation of a number of alternatives. The design study contract covered work done by the contractor over a period of about 5½ years. The point in time when design study work could be considered as ended is uncertain but a date has been generally accepted. No specification was issued at that time, and subsequent changes have either invalidated the standard then accepted or put the change into the category of 'change in requirement'. It was apparent during the investigation that this project suffered from this lack of clear cut design objectives.

In the other project which did not have a Ministry of Aviation design specification at the end of the project study, the first draft specification was published and ratified nearly four years after the contractor began project design work and only four months before the project was cancelled. Consequently all cost estimates published during the project were prepared without the benefit of an agreed specification. This delay in producing an agreed specification handicapped the contractor in three ways:

(a) by impeding progress in some design areas;

(b) by causing uncertainty on interfaces with other parts of the weapon system; and

(c) by reducing the reliability of programmes and estimates by the need to make assumptions on design features likely to be adopted.

Even when the specification was published and ratified substantial uncertainties remained since in many sections it still contained such phrases as 'to the satisfaction of the Project Director' and 'to be agreed with the Project Director'.

The specifications defined by the Ministry in the other eight contracts were largely edited versions of specifications produced by the contractors during the project studies. They were thus a reflection of the extent to which a contractor had been able to resolve areas of uncertainty within the constraints imposed by the duration and financial limits of the project study. It was generally felt by contractors that the effort allowed during project studies was too small to allow sufficient resolution of 'grey areas'.

In one case less than 1% of the resulting cost estimate to completion of development was allowed for the project study. This amount was barely sufficient to cover the production of time and cost estimates, and the design specification was adopted uncritically from the very detailed Research and Development Authority specification on which the project study was based. This design specification later proved inadequate to meet fully the user's needs and major changes became necessary with consequent increases to the cost estimates. In only one case was the amount authorized for the project study as high as 3% of the resulting cost estimate to completion of development. In four cases there was no expenditure on the project study before the decision was taken to proceed with full development.

In the two projects which did not contain a project study period, specifications issued by the Ministry during development were substantially confirmation of performance and characteristics discussed as development proceeded. In one of these two cases they were detailed and precise and it is clear that the care taken gave the company a more realistic appreciation of the content of the development programme, although it is also clear that the absence of a project study (during which draft specifications could have been produced) reduced the reliability of the company's early programmes and estimates of development cost.

2.3 Instructions or guidance on programmes and cost plans

There was a considerable variation in the guidance and assistance given to contractors in the preparation of technical programmes of work and their associated cost plans. At one extreme the Ministry's Project Officer played a major part in their preparation and the Development Cost Plan produced proved of such value to the contractor in monitoring the project that the firm built up a department to extend the methods used, not only to Government contracts but also to private venture development work. The approach used by the Ministry was to request a plan in some detail and then to consider it and discuss it critically with the contractor, paying particular attention to the inclusion of all aspects of development that could be foreseen and the adequacy of the cost estimate for each.

Generally, however, instructions and guidance given by the Ministry were inadequate in that they were too general. Written instructions commonly contained such phrases as 'a disclosure of such technical information in accordance with Controllerate of Aircraft Reports submitted to the Research and Development Authority' and financial information 'as prescribed by the Director of Contracts'.

Where Ministry of Aviation 'Notes for Guidance' were available, contractors did not always comply with them, particularly in regard to the labour and overhead rates to be used in cost estimates, and the Ministry did not enforce them.

In one project in which the contractor received little guidance during the project study, the Project Office of the Ministry stated that it was available on request, but appears to have taken no initiative to ensure that the contractor had adequate guidance.

3. Development programming

3.1 General

All contractors began programming by making broad assessments of the time required to complete major stages of the project, but there was considerable variation in the extent to which individual contractors attempted detailed consideration of the work involved.

Some contractors checked the validity of their broad appraisals by preparing more detailed programmes showing the timing and duration of activities within each major stage of the project. The preparation of detailed programmes required a close examination of each section of development and led to revisions in the original broad appraisal. In these cases programming became a reiterative process in which the original broad assessment was checked and refined by more detailed programmes.

Some contractors did not validate their broad assessments of duration, and although detailed programmes were prepared for some areas of activity at working level, they were not directly related to the overall programme and were not used to amend key milestone dates in it.

All contractors up-dated programmes as work proceeded and as revised Development Cost Plan were required for the Ministry of Aviation. Some contractors produced up-dated overall programmes only at the time of Development Cost Plan revisions, others revised the overall programme more frequently and simply included the latest revision when a revised Development Cost Plan was called for. In some cases revised programmes were simply revised broad appraisals of the overall timescale of each major stage, in others the improvements in technical definition were used to refine detailed programmes and hence up-date the overall programme.

3.2 Establishing initial programmes

Five contractors, all concerned with electronic equipment, broke down the equipment into basic sub-assemblies and considered the design, manufacture, and test of each sub-assembly separately, building up an overall timescale from an estimate of duration on each.

The other seven contractors broke down the project into milestone stages of work and considered the time required to achieve each milestone. In all these cases milestone stages were large areas of work, and varied in the degree to which individual contractors attempted to validate broad assessments by a consideration of constituent activities.

One contractor established four areas of work and assessed the timescale for each subjectively, without reference to historical records of past projects and without validation by detailed programmes.

One contractor developed initial programmes from broad extrapolations of previous similar projects. The programmes so developed were not validated by consideration of constituent activities and contained known defects of past programmes, notably an insufficient build-up of resources in the early stages of development. Later in development a detailed consideration of constituent activities led to a major revision in the overall plan and a large increase in estimated development cost.

One contractor divided the programme into two main sections. The programme for the first section was based on global time estimates by managers from design, drawing office, and manufacturing departments. The timescale for the second section was assessed in broad terms using historical data.

One contractor's overall programme concentrated on flight trials, with a few major milestones, but did not provide for any programming at group or departmental level.

One contractor assessed the overall timescale by a broad consideration of likely work content, compared this with the period of time available to the in-service date, accepted the in-service date, and fitted the broad programmes into the overall timescale. This contractor then assessed the validity of the broad breakdown by preparing detailed programmes for large sections of it using PERT/Time techniques.

One contractor established target dates for a consideration of the in-service date and test requirements. Design, manufacturing, and test programmes were then prepared in detail by operating department managers to marry with these target dates.

The remaining contractor divided the project into six areas of activity and broadly assessed the timescale for each. One area of activity extended for over five years and accounted for about a third of estimated development cost.

No more detailed programmes were prepared for the project as a whole. A substantial slippage occurred in the first part of development and led to postponement of key project dates by other contractors concerned with the project.

3.3 Refinement of programmes during development

Five contractors expressed programmes in the form of bar charts throughout the course of their projects.

Three of these contractors used bar charts which formed an integral part of the overall programme. Periods of revision varied from one contractor who up-dated all programmes three monthly to another who revised detailed and overall programmes once yearly.

The other two contractors using bar charts throughout the project established more detailed bar charts for areas of work as required without incorporating them into the overall programme; consequently the overall programme was not up-dated as a result of failure to meet milestones on the detailed bar charts. One contractor persisted in programming to target dates established early in the project after they had ceased to be realistic.

Seven contractors refined broad programming by the introduction of PERT/Time and in two of these instances construction of networks highlighted serious potential slippage in earlier programmes. The value of networks established by one contractor was limited by their being built around unrealistic milestone dates in the original programme.

Three contractors introduced networks in a small area of work as an experiment and subsequently abandoned their use. In all of these three cases there was evidence of lack of adequate training in the use of the technique before and during its application.

One contractor used networks to validate programmes from the start of the project. This was the first time this contractor had used PERT on Government development work. The first network was essentially simple, containing some forty activities, but although less than a year of development had elapsed at the time of the investigation, the number of activities had been considerably increased and consideration was being given to identifying cost with small groups of activities.

3.4 Resource allocation

Little systematic consideration of resource allocation was evident in the projects investigated. This was particularly so at the initial programming stage. Where demands on resources were considered this was generally done informally at departmental level by group leaders and departmental managers.

3.5 Central programming by the contractor

On four of the projects contractors had established a central function, the responsibility of a senior manager, for programming, estimating, and the monitoring of cost and technical progress.

Five contractors utilized specialist functions within the firm to provide programming, estimat- and monitoring services for the project without combining the responsibility for these functions under one executive.

Three contractors concerned with smaller electronic projects nominated one manager to be responsible for all aspects of the project. This responsibility included programming, estimating, and monitoring, as well as direct line management.

3.6 Overall project programming

Eight of the contractors were involved in multi-contractor projects. Although overall project programming was not examined in the case studies, the following facts were noted:

(a) on one project disagreements between the Ministry of Aviation and a major contractor on programmes remained unresolved for prolonged periods. The uncertainties thus created complicated the programming of another major contractor;

(b) in another project one contractor believed the overall programme to be unrealistic and based his own programme on the assumption that the overall programme would 'slip' by two months each year. This assumption was later justified;

(c) in only one project did we note that overall project planning was being assisted by the use of a level 1 network.

4. Development cost estimating

4.1 Early stages of the project

In four of the projects investigated in the electronics field there was some attempt made by the contractor during the project study to build up a total development cost estimate from a consideration of individual tasks within the overall project. Three of these contractors divided the equipment into sub-assemblies to establish tasks; the fourth divided the programme into main areas of work and assessed in detail the effort entailed by each department in working on each main area. Of these four contractors one did not use any recorded data on past projects to assist in estimating, the estimate for each task being subjective, based on intuition or 'feel'. Two of the four contractors used historic data to establish relationships for the cost of models, and the fourth used extensive analysis of recorded data on previous projects to establish the relationship between engineering effort, assessed subjectively, and other costs: materials and sub-contract, draughtsmen, workshop labour, and overheads.

In the other eight projects estimating was limited to broad areas of work within the overall timescale. One contractor based estimates on a broad assessment of manning levels of each year of development, using manning levels and costs on previous similar projects as a guide. Five contractors assessed costs globally for large areas of work using personal experience and judgement with little or no reference to historical data. The remaining two contractors employed broad parametric extrapolations of costs on previous projects as a basis for a large part of their estimates.

It was generally felt by contractors, even when a project study was undertaken, that the effort allowed during the study was too small to enable reasonably accurate estimates of cost to completion to be prepared.

When a project study did not precede the first Development Cost Plan, the position was even worse, four of the contractors being given only 5 weeks in which to prepare their first Development Cost Plan.

4.2 Revised estimates

In two of the projects investigated less than a year of development had elapsed and no revision to the cost estimate produced at the end of the project study had been made. In one other project no formal contractual agreement was reached until most of the work had been completed, and although the firm submitted six cost estimates in the first two years of work, none were submitted for a further three and a half years up to the time of our investigation. In the remaining nine projects, frequency varied between one contractor who submitted annual revisions to another who submitted revisions quarterly for the first nine months of development and subsequent half yearly revisions for the remainder of the development period.

In two of the projects there was little noticeable refinement in estimating methods as work on the project progressed. In one of these the contractor was hindered by frequent and considerable changes in the requirement to the extent that only two of the five cost estimates prepared were based on the same set of requirements. In the other project, revision of the original global/subjective estimate amounted to no more than arithmetical modifications based on global second thoughts in the light of incurred cost.

In the remaining eight projects in which revised cost estimates were produced, estimating became successively more refined as knowledge increased and grey areas were resolved. Four contractors, who had based initial estimates on global subjective assessment or parametric extrapolation of previous projects, changed to a synthetic build-up of estimates based on objective assessments of cost.

Three contractors, all concerned with electronic equipment, refined initial synthetic estimates by more detailed consideration of smaller areas of work. The remaining contractor's initial estimate was based on a subjective assessment of engineering effort and an historical relationship between engineering effort and other costs. This contractor refined his assessment of engineering effort as 'grey areas' were resolved. But he maintained historical relationships to determine other costs throughout development.

4.3 **Format of estimates**

In five of the projects, those concerned with electronic equipment, Development Cost Plans were required to be submitted on a Ministry of Aviation proforma. This proforma required estimates of cost to be shown separately for each contract item. Within each contract item estimates of cost were required in the following periods of time:

quarterly for the year following the date of the Development Cost Plan,

half yearly for the second year,

yearly for subsequent periods,

and the make up of estimated cost in each period was required to show:

Engineers' salaries

Drawing Office salaries

Wages

Overheads

Materials

Sub-contracts

Profit.

The contractors involved with these projects submitted Development Cost Plans broadly in this degree of detail, although one contractor did not make any distinction between the three grades of labour. In three cases the allocation of spend to periods of time was made on an arbitrary basis, the contractor having first estimated total development cost.

In the remaining seven projects the degree of detail in cost estimates submitted to the Ministry of Aviation varied considerably. One contractor submitted estimates of total cost for each of four large areas of work. Total cost in this case was not analysed to elements (wages, materials, overheads, etc.) and was arbitrarily allocated to individual years. The remaining contractors submitted cost on a finer breakdown of areas of work varying between twelve and sixty areas. Three contractors showed only total cost against each area, three contractors analysed total cost into elements of cost. The division of total cost into periods of time was as follows:

(a) two contractors showed estimated spend in annual periods;

(b) two contractors showed estimated spend in quarterly periods for the first year and annually thereafter;

(c) one contractor showed estimated spend in quarterly periods over the whole of the timescale; and

(d) one contractor showed estimated spend in months for the first year and annually thereafter.

4.4 **Estimating rates**

Generally contractors endeavoured to include labour and materials in estimates at rates current at the time of preparing the estimates although in one project the contractor used rates designed to take account of anticipated escalation of costs during the course of the project.

The overhead rates used by contractors varied between:

(a) current internal budget rates;

(b) the latest 'Agreed Rates'; and

(c) the latest 'Provisionally Agreed Rates'.

In two cases contractors included in overheads staff which might have been regarded as a direct charge, with the result that extremely high overhead recovery rates were established.

5. Monitoring and controlling technical progress

5.1 **Basis of monitoring and controlling**

In two of the projects investigated few detailed programmes had been developed against which progress could be monitored. Delivery dates for systems trials were ascertained and progress was monitored in an extremely broad fashion related to these distant dates. Although both of these contractors introduced some networks during development, these tended to be on relatively small areas of work, and in one case the use of networks was abandoned after a brief trial.

The other ten contractors made some effort to develop operating programmes consistent with the overall timescale by breaking the work into tasks represented either by bars on a bar chart or activities in a network. The effectivness of these programmes as a basis for monitoring and controlling technical progress depended on the fineness of the task breakdown. The use of networks generally provided a sufficiently fine breakdown; programmes based on bar charts usually incorporated large individual tasks and widely spaced milestones, thus making monitoring and control less detailed.

Only one contractor attempted a detailed reconciliation of technical progress with cost. This had been applied and had achieved success in two areas of the project and was being extended at the time of our investigation. In these areas the programme was finely broken down into technically defined tasks and material and manpower requirements were identified with each task. Responsibility for management and the monitoring and control of both technical performance and cost within each task was delegated to one man, generally a working level supervisor.

5.2 **Methods of monitoring**

All contractors relied on informal contact between managers and supervisors at the working level for the day-to-day monitoring and control of technical progress. One contractor relied exclusively on this form of monitoring, which proved adequate because the project was small and the organization for it was product oriented.

In the other eleven projects informal monitoring was supplemented by formal meetings between work supervisors and middle management and between middle and senior management.

On six of the projects a comprehensive system of meetings existed ranging in frequency from weekly to four-weekly. Such structure of meetings generally enabled problems to be discussed at successively higher levels until resolved. Minutes of the meetings were circulated and constituted action reports.

One contractor had a structure of formal meetings which was not fully operative: a large number of meetings were held but these were mainly informal.

Three contractors held formal meetings once a month. These were middle/senior management meetings and dealt with more than one project. In consequence the time devoted to individual projects was limited and attention centred around those projects which were encountering difficulties. Minutes of these meetings were distributed as action reports but were naturally not very detailed being confined to projects and areas within them encountering serious difficulties.

The remaining contractor held formal weekly meetings both at individual project level and at middle/senior management level, but at these latter meetings an individual project was only reviewed about once in every eight meetings unless serious difficulties occurred.

5.3 **Reports**

On seven of the projects investigated a formal written report was prepared by a member of project management for discussion at meetings and circulation to senior members of the contractors' management. In every case where this was done, the report was produced monthly and was in the nature of a general review of achievement and progress, highlighting difficulties.

In four of the projects where PERT networks were being used, regular print outs were available both to working level managers for day-to-day monitoring, and to senior members of management. In the other two cases where PERT was used, it had been introduced only a few months prior to our investigation and work on validating the networks was still in progress. It was intended to use PERT for monitoring technical progress as soon as this preparatory work had been completed.

Where PERT networks were not in operation, there was little available to management in the form of technical progress information other than the monthly reports referred to above, the minutes of meetings referred to in 5.2, and information gleaned from day-to-day informal contact.

In ten projects contractors submitted formal written reports on technical progress to the Ministry of Aviation at frequencies varying between monthly and quarterly. These reports formed the basis of discussions at formal progress meetings with Ministry representatives which also varied in frequency between monthly and quarterly.

Two contractors did not submit formal written reports on technical progress to the Ministry of Aviation. One of these contractors reported progress verbally at monthly meetings with Ministry representatives. In the other project the contract did not call for written reports on technical progress and none were submitted. No formal regular meetings to discuss technical progress were held between the contractor and representatives of the Ministry.

6. Monitoring and controlling cost progress

6.1 **Integrated control of cost and technical progress**

In the twelve projects investigated only one contractor had procedures for monitoring and controlling cost progress integrated with those for monitoring and controlling technical achievement, thus providing detailed correlation between the two. This sub-section is a summary of the procedures adopted by this contractor. The procedures adopted in the other eleven projects are summarized in the sub-sections which follow.

The technical programme was divided into broad areas of work, each broad area then being further divided into major tasks, major tasks being divided into minor tasks. The broad aim of the tasks system was to define a discrete area of work and its total requirement in terms of technical, material, and manpower resources. At the time of our investigation not all major tasks had been broken down to minor tasks, but the procedures were being continually extended with the intention of applying them to all areas of the project.

The responsibility for the management and control of each task in terms of cost, time, and technical performance within an agreed budget was delegated to one man. The man responsible for a task in this way was generally a working level manager, obliged to draw on departmental resources in fulfilment of his responsibilities, and therefore not having full authority for all aspects of the task.

Cost collection procedures enabled actual costs to be reported and compared with budgets in some detail for each minor task: thus each manager received reports appropriate to his responsibility which were capable of upward summarization to successively higher levels of management comparing cost and technical achievement with budget for successively larger areas of work. The time lag between the end of a period and the presentation of reports was usually about two weeks.

Monitoring of both cost and technical progress was supported by a comprehensive series of formal meetings throughout all management levels ranging in frequency from weekly to monthly.

6.2 Non-integrated control of cost

All but one of the contractors engaged on the other eleven projects investigated, operated a system of internal management accounting which reported expenditure against budgets by functional areas of the organisation. Such systems did not always provide a means of monitoring costs on individual projects, since individual projects were not identified in reports. This section is concerned with the procedures established to make good this deficiency.

The effectiveness of procedures to monitor and control project costs was limited by the extent to which the project was divided into individual areas of work to which budgets were applied.

Seven contractors used both the work breakdown and the estimated expenditure in their Development Cost Plans against which to monitor actual expenditure. Three of these contractors established budgets of expenditure by months using somewhat arbitrary methods (one contractor spread each year's spend equally into four-weekly periods). The remaining four contactors did not prepare separate budgets other than the estimated expenditure each quarter recorded in the Development Cost Plan.

Two of the seven contractors further subdivided each item in the Development Cost Plan and allocated a limit of spend to each subdivision. In both cases the subdivisions numbered less than ten per item and the limit of spend was in total only, not spread over time. The limit of spend was designed to ensure that senior management was informed when the limit was reached.

One contractor built up a programme of work from a subdivision of items in the Development Cost Plan and allocated to each subdivision the requirement in terms of manpower and materials by months which was then converted into monetary terms. This document provided a sound working programme, but was of limited use in monitoring expenditure since costs were not collected under the same subdivisions of Development Cost Plan items.

One contractor established budgets for each major section of the programme by four-weekly periods in terms of total expenditure only.

One contractor operated the project for a period without any form of budgeting but later introduced budgets in total figures only for large areas of the programme.

The remaining contractor operated throughout the project without establishing any form of budget. Consequently, direct control of cost was not exercised and overall control was undertaken only within the contractual limits of liability.

All contractors prepared and presented monthly to management actual expenditure incurred on the project. All contractors collected and reported expenditure in greater detail than that for which budgets were established, but presentation of information not compared with a budget was meaningless as a medium for control.

Of the contractors who had established budgets, three did not show budget/actual comparisons on reports presented to management.

One contractor considerably refined his cost collection procedures during the course of the project, making it possible to collect costs by individual small tasks within each stage of development: but the absence of budgets precluded any meaningful comparison by tasks.

Speed of presentation of cost information varied considerably over the projects investigated. Two contractors had information available to management within ten days after the end of a period. Six contractors did not have information available in less than four weeks, and in two of these the average time between the end of a period and the availability of information was six to eight weeks.

7. Unit production cost estimating

The methods of unit production cost estimating varied considerably in the projects investigated. Within each project methods tended to change and become more refined as development progressed and a better appreciation of detail became available.

No formal production cost estimates had been made by one contractor, whose project was in the very early stages of development. In the other eleven cases our studies have listed fifty-six separate estimates of unit production cost, some of which were made for Ministry information and some entirely for the contractor's internal use. These estimates have been divided into five categories:

(a) Global—estimates made on a subjective basis and in overall terms;

(b) Comparative;

(c) Parametric;

(d) Synthetic—Broad; and

(e) Synthetic—Detailed.

The results of this analysis are shown in the chart below, displayed against a time scale which represents the proportion of project time that had elapsed when each estimate was made. The zero on the time scale corresponds with the start of the project study or equivalent. Estimates made before this time are therefore shown against the negative part of the time scale. The 100% on the timescale is based upon the latest estimate of development duration in each case. Individual contractors are identified by a code letter.

This chart shows that:

(a) seven contractors moved from the more approximate methods of estimating to more detailed synthetic estimating as development proceeded; and

(b) no contractors produced detailed synthetic estimates until some thirty to forty per cent of project time had elapsed.

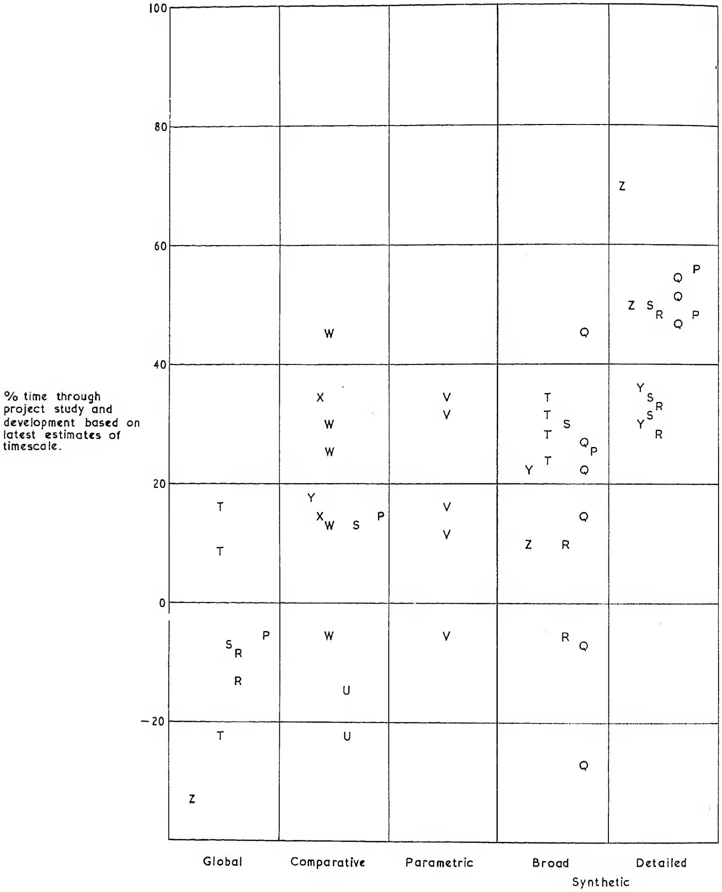
The frequency with which production cost estimates were made by contractors varied from one who made seven separate estimates in the three years following the start of the project study, to another who made four estimates in five years.

In four of our twelve case studies the Ministry approved development without receiving any formal production cost estimate from the contractor. One of these four projects had as one of its main features the development of an equipment of low production cost.

In five of the twelve projects contractors used formal learning-curve relationships to assess the reducing future cost of production as experience accumulated. The remaining contractors calculated only a single average unit cost.

In five of the projects, contractors were influenced by having rough target production costs available to them from the start of the projects.

Changing Basis of Estimates



8. Records linking performance or technical characteristics with cost

In only three of the twelve cases studied did the contractors rely upon statistical or parametric extrapolations from the results of past projects when making their early development cost estimates. These contractors argued that, until development had progressed far enough to enable the equipment to be defined in some detail, only this type of extrapolation was possible.

They reconized the need for detailed modifications to the results of calculations to allow for changes in complexity not automatically incorporated. Two of them maintained extensive analysed records of past costs and were very active in investigating possibly useful relationships between cost and various aspects of the equipment developed.

None of the remaining nine contractors used formal extrapolation from historical records when estimating development costs. A common argument was that techniques and materials changed so much from one project to the next that a comparison could be misleading. However, three of these contractors kept records from which some of their estimates made by other means could be checked for plausibility.

Ten contractors kept accessible records of production costs on past equipments. Four of these had analysed costs to give a predictable relationship with the production costs for new products, using various common factors as a basis for comparison. The remainder had found no suitable basis and simply tabulated past costs for named components so that future estimators could make ad hoc comparisons and adapt costs to suit new designs.

Three of the contractors described various rules-of-thumb to assist with production cost estimating. A common rule related the total prime cost of the manufactured equipment to the cost of its principal components.

9. Value engineering

In none of our twelve case studies did we see Value Engineering being applied fully, and to the whole equipment being developed, with the intention of obtaining the lowest combined development and total production costs.

In five cases, formal Value Engineering techniques were being applied to small selected parts of the whole equipment: in two of these cases the activity was the result of a separate Ministry contract.

Two of the contractors, who were not using Value Engineering on the projects that we investigated, claimed to be using it effectively on other projects.

On three of the projects, formal cost reduction activities had been carried out by special teams employing some Value Engineering techniques but not the full methodology.

Two other contractors made no claim to be undertaking any formal cost reduction activities and maintained that cost must be secondary to high performance and low weight.

Staff on all but three of the projects that we investigated were enthusiastic about Value Engineering as an idea: it was common to meet engineers and designers who had been on training courses and were familiar with the basic principles and techniques. Contractors' managements often expressed a hope that the 'cost-consciousness' inculcated by such training would result in the men producing lower-cost designs. It was not possible to check whether this hope was being fulfilled.

Contractors carrying out formal Value Engineering claimed savings ranging from 4% to 17% of total production cost.

10. Design changes

Once drawings had been 'frozen' for production, all contractors expected to have to comply with Ministry procedures for Amendments and Modifications to the design. Before the freezing of drawings, practice varied.

In four of the projects that we studied, formal procedures were in use early in development, with committees meeting weekly or fortnightly to consider whether each change should be allowed and, if so, how it could best be introduced. Three of these procedures also included a consideration of the effect of each design change on development or unit production cost. Two of the four procedures applied only to part of the range of equipment being developed: in each case the rest of the equipment was controlled by less formal means.

Similar informal procedures were used on the whole of their development by five of the contractors studied. A typical arrangement was for proposed changes to be passed for approval by the manager in charge of the project: no provision was made for any specialist evaluation of the cost consequence of the change.

In two cases, a compromise arrangement was used. Changes were documented and notification of them was circulated to everyone who might be concerned. No committee met to consider the best way of implementing them and in neither case were the cost effects of changes calculated.

The remaining contractor applied change procedures only to his sub-contractors. Full formal procedures to cover internal work as well are now being introduced.

11. Reasons for changes in estimates

Our terms of reference required us to report on the difference between each contractor's earliest and latest estimates of development cost, analysed if possible into prescribed categories. In five cases we have been unable to do this. One project had not been running long enough for significant differences to have arisen. In another case, comparisons were meaningless because very large changes in the requirements had taken place. Three other studies showed that estimates were not in sufficient detail to allow the figures to be rearranged in the form required.

Even in the seven remaining cases, where the required analysis has been made, some subjective judgement has had to be used, both by the contractors and the consultants, in deciding which category certain items belong in. Loosely defined requirements and a failure to specify precisely the proposed methods of meeting them have made objective analysis impossible. Consequently, conclusions should not be drawn from the analysed data for any single project: it is safer to draw conclusions which appear to be supported by all or a majority of the projects.

The 'original' estimate quoted is not necessarily the first estimate produced by contractors but is the earliest estimate considered to be sufficiently valid to use as a basis of comparison. The Table shows the increase in estimates for each of three groups of reasons. The increases are shown as percentages of the 'original' estimates. Also shown are the points in each project's time scale at which the estimates were made.

	Z	Y	O	V	U	T	R
Reasons for differences	*% increases*						
Ministry reasons	Nil	2	—12	17	51	25	3
Changes in or additions to the Ministry's requirement.							
Lack of definition of the requirement.							
Contractor reasons	23	—7	Nil	3	8	23	6
Changes in the method of meeting the requirement.							
Under estimation of the cost of the method.							
Escalation of costs							
Changes in labour rates or material costs, overhead or profit rates.	18	12	17	19	17	12	16
Total % increase	41	7	5	39	76	60	25
% of planned time elapsed before 'original' estimate	13%	15%	6%	32%	*	*	8%
% of planned time elapsed before latest estimate	52%	38%	18%	51%	25%	38%	51%

* Estimates made before project study or equivalent.

The actual increases ranged from £50 K to £23 M and there was a marked tendency for the larger percentage increases to occur in the high cost projects.

The tabulated figures show that roughly equal increases have been attributed to reasons in group (i)—'Ministry reasons'—and to those in group (ii)—'Contractor reasons'.

The changes shown in group (iii) are nearly all significantly greater than the effects of normal wage inflation. The excess has been attributed in each case to a change in the rate of some category of overhead cost.

The case study coded 'V' in the Table shows a 39% increase in estimates even although the first estimate was made after one third of the project time had elapsed. This poor performance was largely due to repeated alterations in the requirement during this period.

12. Contractual aspects

Five projects were delayed between the project study (or equivalent) and full development. The three projects with the largest delays (9–12 months) were kept going by holding contracts but these were of low value, allowing limited work at a rate which was well below the planned rate: contractors complained that teams had to be disbanded and that engineers became dissatisfied and resigned. One contractor had only one engineer left from the project study team when full development started.

One further project would have been held up in this way for a year if the contractor had not been prepared to continue with full development without pause on the informal assurance that a further contract would be placed. Momentum was maintained and the work was subsequently covered by a retrospective 'Initial Development Contract'.

Five projects continued on holding contracts into the main design phase. Much uncertainty was generated because work was authorized in very short periods, typically of 2–3 months each. The overall periods of these contracts were:

22 months
22 "
34 "
48 "
65 "

The project which continued on this basis for 48 months was without contract cover on no less than 34 occasions.

One contractor complained that he did not receive contract cover until 19 months after he had been told that his project would be supported. This reduced the enthusiasm of the development team and also reduced the degree of Ministry control, because he produced no progress reports during this time.

Two contractors severely restricted the supply of information on the work being done pending the receipt of what each considered to be formal contract cover.

APPENDIX L

(Reference: Chapter 7)

The Control of Research and Development:* Principal C.A. and C.G.W.L. Instructions

1. Subject	2. CGWL Notice	3. Av.P.88 Chapter †	4. CA Notices
1. Formulation, assessment, and acceptance of Staff Requirements	101	105	Reqts. 2
2. Feasibility studies, project studies and holding contracts	198	109	—
3. Approval for development: procedures of the Operational Requirements Committee and the Weapons Development Committee	175 177	102 104	— —
4. Purchasing policy, selection of contractors, competition, and contractual arrangements	110 157	801 110	Ctts. 13 Orgn. 34
5. Definitions and functions of technical authorities managing and co-ordinating development projects	103 104	301 108	— Acft. 8
6. Responsibilities for the financial management of development projects	158	106	—
7. Project management: duties of Development Project Directors, etc.	105 183	111 107	— —
8. Development programme dates and Confidential Policy costs	174 187	113 114	Orgn. 32 Orgn. 33
9. Instructions to contractors—Technical Procedure and General Design Requirements	122	304	—
10. Estimates of production costs	121	118	—

---

* Other instructions issued by the Controllerate of Aircraft (C.A.) and the Controllerate of Guided Weapons and Electronics (C.G.W.L.) refer to this subject: only the most important are identified in this table.

† Av.P.88 (Handbook of CA Instructions) is still in the course of preparation, and those CA instructions which have not yet been issued as a Chapter of Av.P.88 are identified by a reference to the existing CA Notice in Column 4.

APPENDIX M

(Reference: Chapter 11)

Programming, Estimating, and Control of Development Projects: Handbook of Procedures

1. The Handbook of Procedures describes an integrated set of procedures for programming, estimating, and control, on Ministry-sponsored development projects. These procedures are intended as an aid to contractors in the effective management of development. They are also intended to assist Ministry Project Officers in the evaluation of proposed projects, and in the oversight of development contracts.

2. For convenience, the Handbook has been separately bound, and comprises Volume 2 of this Report.

APPENDIX N

(Reference: Chapter 11)

Handbook of Procedures: Supporting Action by the Supply Department

The Handbook of Procedures (Appendix M) described an integrated set of procedures for programming, estimating, and control on large development projects. These procedures are intended as an aid to contractors in the effective management of development. Many of the actions recommended for contractors require complementary actions by the supply Department and a check list of the latter is given below. This list is not and is not intended as a comprehensive list of the duties of a Development Project Officer. The references in brackets are to the Handbook of Procedures (e.g. C.2.2. refers to Chapter 2 of the Handbook, section 2).

1. All supply Department project staff should become familiar with the procedures described in the Handbook of Procedures.

2. Experience has demonstrated most forcefully the ill effects that follow from incomplete or frequently-changing statements of the requirement. No project should be initiated until there is evidence that a firm requirement for the main performance parameters has been thought out and agreed by the customer Department(s). Thereafter, changes in requirements should be very strictly controlled.

3. In addition to stating the main performance parameters of the equipment as fully as possible, all requirements should give the timescale within which the equipment is to be developed. This is particularly important where competitive proposals from different contractors are being sought.

4. Requirements should state what the equipment has to do without prejudging the engineering means to be used to do it.

5. Adequate time and cost should be allowed for all contractors' pre-development studies and contractors should be asked to confirm that the allowances given to them are sufficient. The time and cost needed may vary widely with the circumstances, but the following suggestions may serve as a starting point when officers are considering what is appropriate to a given project:

Stage	*Time*	*Cost*
Feasibility	6 months	½% of the total development project (C.2.2)
PD–1	up to 9 months	5% of the total development project (C.2.4)
PD–2	12–15 months	10% of the total development project (C.2.5)

Contractors should not be restricted to paper studies at any stage; they should be encouraged to build models, carry out tests, etc., to validate their assumptions as early as possible.

6. Every assistance should be given to the contractor when he is preparing his development programme and estimate, so that they may be in a form suitable for rapid and effective appraisal. In particular:

    6.1 The contractor's initial Programme Breakdown should be discussed. It should be checked for logic and important features, such as the number of models or the number of test rounds for each phase, should be agreed. (C.3.3.12)

    6.2 Appropriate check lists should be kept up-to-date and made available to the contractor so that he omits nothing of importance from his development programmes. (C.2.4)

    6.3 The contractor should be guided in his choice of method for applying programme reserves and in the appropriate allowance to make at each stage. (C.3.3.11)

6.4 The contractor should be guided in his selection of rates for converting time estimates to cost. Rates should be selected which are simple to apply and which will require as little change as possible when they are eventually replaced by 'Agreed Actual Rates'. (C.6.8)

7. The contractor should be told what production quantities and rates are likely to be required. This will help him to prepare his estimates of unit production cost. (C.7.3). The basis of any parametric or comparative estimates should be checked with historical data from the contractor and from any other available sources. (C.7.5)

8. When production quantities or costs are expected to be large, consideration should be given to asking the contractor to submit proposals showing the reduction in unit production cost that could be secured by the application of Value Engineering and the increase in development cost and time that would be required. With this information, the supply Department can decide whether or not to include a specific requirement for Value Engineering in the development contract. (C.7.2)

9. A decision on full development should be made before the end of the Project Definition contract (C.2.5). If a decision is delayed, short-term contracts should be placed which, whenever possible, should allow development to build up at the rate envisaged by the development programme.

10. Supply Department officers will need to appreciate the significance of the reports on project progress that will be supplied by contractors:

    Summary reports on technical progress (C.5.5)

    Summary reports on cost progress (C.6.5)

    These reports will form the agenda for progress meetings (C.5.7) at which officers will be expected to comment upon the likely adequacy of action proposed to correct any deviations from the technical programme or cost budget. (C.5.8)

11. The programme for a project will often include some activities which need to be performed by the supply Department. These activities should be monitored, and any slippage controlled with great care so that the contractor is set an example of forethought, energy, and determination. (C.3.3.5)

12. Large projects frequently require the co-operation of a number of contractors, supply Department branches and Government Establishments. The problem then arises of how to plan for the co-ordination of their work; programmes need to allow for numerous interfaces for the exchange of information, instructions, or hardware; control needs to ensure that interface dates are kept, or that the most vigorous and concerted action is taken to recover any ground lost if they are not. (C.3.3.6)

Printed in England for Her Majesty's Stationery Office
by Hull Printers Ltd., Willerby, Hull, Yorks.

Dd. 142224. K.12.